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EXPERIMENTAL TECHNIQUES IN HOLOGRAPHIC INTERFEROMETRY

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

Van Houten (V168)

EXPERIMENTAL TECHNIQUES IN HOLOGRAPHIC INTERFEROMETRY

by

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June 1973

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Experimental Techniques In
Holographic Interferometry

by

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Lieutenant, United States Navy
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requirements for the degree of

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ABSTRACT

Fiber light guides are used in conjunction with holographic interferometry. A Michelson interferometer was constructed to test for temporal coherence of light passing through fiber optics. A finite-fringe hologram of a no-flow condition was taken to prove the feasibility of applying fiber optics to this field of flow investigation.

The effect of opaque bodies on interferometric data inversion was sought. Two schemes for replacing the missing fringe data were used to see if the accuracy of the calculated density fields could be enhanced.

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I. EXPERIMENTAL WORK ON FIBER OPTICS

A. INTRODUCTION

Holographic interferometry is an invaluable and frequently used tool in modern flow field visualization. Numerous articles have reported on the application of holography to interferometry, among the first of which was presented by Heflinger, et al. [Ref. 1]. The history, the theory, and diverse applications of holography are presented in Collier [Ref. 2]. Holographic application to interferometry has been extensively investigated for pure gas flows [Ref. 3], for flows around transparent bodies [Ref. 4], and for flows around opaque bodies [Ref. 5].

The principles of holography have been known since 1947 when Gabor developed the principle as an improvement for electron microscopy [Ref. 2], but the current scientific applications awaited the development of a coherent visual radiation source. Previously, flow field visualization relied on interferometric techniques utilizing light sources of poor temporal coherence.

The specialized area of interferometric holography includes such techniques as real-time, time-averaging, stroboscopic, and time-lapse. They are discussed in Ref. 6. The time-lapse technique, also referred to as double exposure, is used for flow field visualization. This technique involves superimposing the phase and amplitude information of a flow condition upon that of a no-flow

condition. An improvement to time-lapse holography was achieved by the use of diffusing screens positioned in the scene beam. The idea was advanced by Heflinger [Ref. 1], while Gates further developed the concept [Ref. 7]. In normal side-band holography, each point on the object acts as a diffusely reflecting light source. Light reflected from all points on the object can mutually interfere with light from all other points. The total interference pattern produces a three-dimensional image. This three-dimensionality can be obtained in holographic interferograms of transparent objects by introducing a diffusing glass plate in the scene beam just prior to the test section.

Two varieties of time-lapse holography are the infinite fringe and the finite fringe methods. Infinite fringe patterns occur when the wave fronts of the separate exposures see exactly the same optical arrangement. Finite fringe patterns occur when a finite displacement is introduced in the optical arrangement between exposures. The fringe for the undisturbed region are parallel, equispaced lines which will be perpendicular to the direction of translation. These parallel, equispaced lines form a convenient scale for determining the fringe shift values in the disturbed region of flow.

The double exposure has the advantage of relaxing the tolerances of the optical equipment. Both flow and no-flow beams travel common optical paths which effectively eliminates the interference fringes from optical imperfections

of the experimental apparatus. This phenomenon is such that good quality holograms can be constructed with extremely rudimentary setups and optical components.

One final improvement in technique was required for the true versatility of holographic interferometry to emerge. Mechanical stability of the experimental components was required to achieve proper fringe interference patterns. The stability needed to be on an order of the wavelength of the light being used. The pulsed laser has eliminated stability problems during exposures by its ability to "freeze" the flow through exposure times in the tens of nanoseconds. Inherent in the pulsed laser is a loss of coherency length as compared to the continuous-wave laser (c.w. laser). Coherency lengths are strongly dependent on the number of modes that can oscillate simultaneously. For pulsed lasers, coherency lengths are normally on the order of tens of centimeters.

There is a need to relax the typical experimental arrangement to further expand the versatility of holographic interferometry. Data for flow field visualization must normally be collected from wind tunnel tests which only simulate real life. Freedom from the laboratory environment could be achieved by adapting fiber light guides to channel coherent light to and from real-life flows. Interferometric data could thus be collected on many interior flows or hazardous flows which do not lend themselves to standard experimental setups. Real-life flows such as inlet flows

or compressor flows could be investigated. To determine the feasibility of applying fiber optics in this fashion, a basic interferometric experiment was conducted using a fiber light guide to transmit a portion of the laser beam to the photographic emulsion.

B. EXPERIMENT

1. Equipment

The initial endeavor to achieve holograms using fiber optics was made with a 15 m.w. continuous wave helium-neon laser. Having found this inadequate, a Korad K-1 pulsed ruby laser with a Pockels cell Q-switching device was used in its place. The laser operates at a wavelength of 6943 Angstroms and has an effective exposure time of 20 nanoseconds. The fiber optics employed were 1/4-inch bundles, one being twelve inches in length and the other 24 inches. The c.w. laser was used for alignment of the pulsed laser beam through all the optical components. Also, the c.w. laser was used to establish the relative intensities of the scene and reference beams. Optical components consisted of several concave lenses, a beam splitter which was 20% reflective, front surface mirrors, and diffusing glasses of several different densities. A precision X-Y translating stage was used to achieve finite fringe lines. A schematic of the experimental arrangement is shown in Figure 1. Because the experiment was to be a double-exposure hologram, the quality of the optical

components was not of concern. An optical bench for isolating extraneous vibrations from the experiment was also deemed unnecessary due to the high speed exposures being used. The photographic emulsions used were AGFA-GEVAERT 10E75 holographic plates.

2. Michelson Interferometer

A Michelson interferometer [Refs. 2, 6, and 8] was constructed to make an initial start in determining the feasibility and the associated problems of holography employing fiber optics. One path length of the interferometer was replaced by a fiber light guide. [Fig. 2] The refractive index for the optic bundle was taken as 1.5 and an appropriate compensation was made in the optic path lengths. The interferometer is a test for temporal coherence of light. Temporal coherence for laser sources of light is extremely good and is the basic quality allowing for the development of the modern expansion of holography. When the paths are exactly matched, a well-defined circular interference pattern should be visible on the screen. If one path length is changed (ΔL) the fringe pattern becomes less distinct. The point at which the fringe could be considered no longer existent is a subjective quality and the value of $2\Delta L$ at this arbitrariliy accepted visibility of the fringe lines defines the temporal coherence length of the laser. Pulsed lasers have coherence lengths on the order of 10 to 20 cm.

3. Holographic Arrangement

The holographic arrangement is illustrated in Figure 1. The pulsed laser was mounted on an optical rail along one side fo the work table. In its path a removable front surface mirror was positioned which directed the alignment laser along the identical path as the pulsed laser. The high intensity pulse was spread by a concave lens to prevent the high intensity beam from scoring either the beam splitter or the fiber optics. The beam splitter was 20% reflective allowing the greater amount of energy to enter the fiber optics. It was necessary to direct a high percentage of the energy into the fibers for there is a 43% internal optical loss associated with the 24 inch length. Also, the divergence of the beam leaving the fibers is sufficient to cause a rapid loss in beam intensity as the free-air path length of the beam is increased. The reflected beam was used as the reference beam. It was directed to a front surface mirror and through two concave lenses to the photographic surface. The other portion of the beam entered the fiber bundle after passing through the beam splitter and was then directed to the photographic plate. Both beams had a 30% incidence angle to the normal of the photographic plate. A precision X-Y translation stage was used in the scene beam. It was initially used to translate the fiber ends and later to translate a diffusing plate placed in the scene beam.

Alignment and the relative intensities of the scene and reference beams were achieved with the c.w. laser. Alignment was achieved in the following manner. At two points 0.5 meters apart along the optical, rail blackened photographic papers were positioned. These were burned with the pulsed laser using a 1.5 mm. aperture. Pin holes were made in the center of each spot. A removable mirror was placed on the rail which reflected the c.w. laser beam through the two pin holes. This beam was a visual equivalent of the invisible pulsed laser beam and could be readily aimed through the optical components. Each beam was centered on a target grid set in the photographic plate holder.

The loss of intensity through the fiber optics was not a controllable factor and as such, all adjustments for the relative intensity of the two beams were made to the reference beam. Two concave lenses closely spaced gave the needed control of the divergence of this beam. White sheets of paper were held in front of each beam and a visual estimation of the intensities was made. It was attempted to have the reference beam from two to three times as intense as the scene beam.

The equivalent free-air path lengths for both beams was approximately 190 cm. The free air portion of the scene beam, that portion from the exit of the fiber optics to the photographic plate, was determined by two factors;

having the fibers far enough away to achieve maximum coverage of the photographic plate, and not being so far as to seriously diminish the intensity of the beam.

4. Testing Procedure

To initiate testing, all alignment devices were removed and a 2.5 mm. aperture was placed in the transverse mode selector. It proved prudent to make an additional test for correct alignment and relative intensities before proceeding with the actual experiment. This was accomplished by making two initial exposures, allowing only one beam at a time to expose each of two different plates. After developing these plates, a more reliable visual comparison could be made of the two beam intensities. This also gave assurance that both beams were sufficiently centered on the photographic plate.

To prove the feasibility of holographic interferometry employing fiber optics, an initial step was to achieve finite fringe lines of a no-flow condition. Since the fibers consist of a large number of independent light sources, each one emanating from the end of each individual fiber, it was felt at first that this property of the light guide would obviate the need for a diffusing plate in the scene beam as is customarily used. As such, the fiber bundle was attached to the X-Y translation stage. Between exposures the stage was translated 0.003 inches horizontally to produce vertical fringe lines. Additionally, the experiment was performed

using a diffusing plate translated in the same manner, in place of translation of the fiber optics.

C. RESULTS

1. Michelson Interferometer

The Michelson interferometric experiment produced positive results. A fringe pattern was observed on the screen from the interferometer employing the fiber light guide. The temporal coherence was preserved through the fiber optics. It became evident that the experiment was highly sensitive to vibration. This portion of work was accomplished on a vibration isolating optical bench. When the experiment was initially performed without fiber optics, the fringe pattern would waver whenever slight shocks were induced in the concrete floor of the test room. Once the fibers were positioned, the sensitivity to vibration was greatly heightened. The fringe pattern was observed only after extensive and minute adjustments were made to the optical components. The fringe pattern was seen for but an instant. Because of the difficulty of stabilizing the optical arrangement, no further investigation was made to determine whether there was a degradation of coherency length by the fiber optics. The apparent increased sensitivity to vibration of the fringe formation necessitated using high-speed exposures achieved with a pulsed laser for all further work.

2. Holographic Experiment

The first phase in the experiment sought to ascertain the need for a diffusing plate. In view of the large number of individual fibers contained in the light guide, would each fiber act as an individual light source and produce a similar effect to that of a diffusing plate? Initial holograms were made of a transparent phase object, a rhombohedral plastic form, as well as finite fringe lines. The technique proved unsuccessful. Finite fringe lines were not produced. However, a hologram of the phase object was achieved. It was of poor quality and contained only a picture of the light emitted by the fibers and several high-intensity reflections of light from the inner walls of the rhombohedron. The appearance was exactly that of previous holograms attempted where a diffusing plate was not incorporated.

Further testing was limited to achieving a finite fringe pattern using the diffusing plate attached to the translating stage. Vertical fringe lines of a no-flow condition were achieved. The fringe lines were clearly visible, but were confined to only a portion of the photographic plate.

During the alignment portion of the experiment, it was noted that the uniformity of the beam from the fiber optics was greatly influenced by the positioning of the incidence beam. The most uniform pattern was achieved by an incident beam covering approximately one third of the

area of the fiber ends. This result was enhanced if the beam was directed off center. Minute changes in its position on the fiber ends greatly influenced the quality and focus of the emitting beam. Since the pulsed beam is unobserved, no positive control of the beam from the fibers was assured. It would be reasonable to suspect this uncertainty for the number of failures and the eventual poor quality of the holograms achieved.

II. THEORETICAL INVESTIGATION OF LIMITED FIELDS OF VIEW IN HOLOGRAPHIC INTERFEROMETRY

A. INTRODUCTION

An attempt was made to further investigate the problem of data reduction for supersonic flows containing opaque bodies. An initial effort toward this was presented by Jagota and Collins [Ref. 5]. Known values of density along various lines of sight were obtained from AGARD [Ref. 9] for a specific cross section in the flow about a cone. To diminish the effect of the presence of the cone in the flow, a fictitious constant density distribution equal in value to the density at the cone surface was added. The new density field, which now covered the entire test section area, was used to calculate a fringe number array that would have resulted from such a density distribution. These data were then reinverted to obtain a density distribution which was compared to the original density. Reference 8 contains the computer program used for the data reduction.

Further research into flow around opaque bodies has been facilitated by the development of an alternate computer program using a Fourier transform method in place of the Fourier expansion used in Ref. 8 to solve the pertinent equations. Van Houten discussed this method in Ref. 10. The main advantages of the program are in the computational time required and the numerous options available to the user.

Computational times on the order of two minutes made the program by Van Houten ideally suited for exploring different schemes to calculate the density field around an opaque object.

B. PROCEDURE

Because one would normally be starting with experimentally observed fringe data, manipulation of this information was chosen as a starting point instead of the density field change used in Ref. 5. A fictitious density distribution was formulated corresponding to Fig. 8 of Ref. 10. The relative refractive index function was given by:

$$\begin{aligned} f(X,Y) &= (1 - Y^2)\, e^{-2X^2} & R &\leq 1.5 \\ &= 0 & R &> 1.5 \\ R &= X^2 + Y^2 \end{aligned} \qquad \text{eq. (1)}$$

The computer program used this input to calculate a refractive index field over a 4 in. by 4 in. cross-sectional area. The field was calculated at 101 equispaced points on both the X and Y axes. Mode 1 of the program starts with the relative refractive index function, calculates an initial refractive index field at selected points from this, computes the fringe shift that would be observed from the field, and recalculates a new refractive index field from the fringe shift information. These calculations were used as standards against which other flow fields were to be compared.

Two experimental phases were studied; Van Houten's Fig. 8 was centered within the test field, and the same figure was translated 0.25 in. along both axes. The KSYM argument of the computer program, which is a measure of symmetry of the field about the origin, changed between cases. The translation destroyed the symmetry found along both axes in the original figure.

Mode III of the program uses fringe information supplied as data, and from it calculates a refractive index field. To simulate the presence of an opaque body immersed in the flow, fringe information obtained from Mode I was blocked over a portion of the field. The blocked portion was the center portion of the flow field. This portion of the fringe data blocked by the presumed body was restored using two numeric schemes. The reconstructed fringe shift information was used to recalculate the refractive index field. This allowed for a direct comparison between density distributions of the free flow with that of a flow around the opaque body.

The program from Ref. 10 was modified for this use and is presented in Appendix A. Two schemes were used for reconstructing the lost fringe information. The first method used a U. S. Naval Postgraduate School Computer Library subroutine titled INTRPL. This was incorporated in a subprogram [Appendix B] that read in the entire fringe shift information and automatically destroyed the middle quarter of the data. INTRPL used the remaining field to

recalculate the missing portion. The second scheme [Appendix B] filled the same missing information with a linear interpolation. The two newly constructed fringe number arrays were reinserted in the main computer program under Mode III and the resulting refractive index fields were obtained.

C. RESULTS

Six separate computer runs were made, the first three dealing with the function centered on the X- and Y-axes, and the last three dealing with the displaced function. Each group of three runs commenced with a given refractive index function from which was calculated the refractive index field at selected grid points using the Mode 1 operation. All subsequent runs were done under Mode 3. The second run of each group used the fringe shift array as modified by the INTRPL subprogram. The third run used the same information as modified by the linear interpolation subprogram. A diagram of the calculating procedure is given in Figure 3.

Contour plots of all refractive index fields were used to compare results for the different cases. Contour lines were produced at 0.1 intervals from the maximum function value of 1.0 to the minimum value. Comparisons among the contour plots were made using two different criteria; errors of the test case values from the values of the standard case in percent of the maximum value of the function, and the number of calculation grid points between

equal contour levels of each graph. Comparisons were terminated at the boundary of the simulated body. The body consisted of a circular region of a 0.5 in. radius located at the center of the cross-sectional area.

1. Centered Function

Figure 4 presents the refractive index field calculated by Mode 1 using the density function given in Equation 1. This is the standard of comparison for the other centered cases. In Fig. 5, the center portion of the fringe array has been removed and replaced by the subroutine INTRPL. In Fig. 6, the center portion of the function has been removed and replaced by a linear interpolation.

The greatest error encountered in comparing the standard, Fig. 4, with Fig. 5 was at the surface of the body. This error was on the order of 8%. Errors around most of the body were approximately 5%. Elsewhere in the flow, the maximum error observed was 2.5%. Generally, the lower-valued contour levels away from the body were very closely matched.

A comparison of Fig. 4 and Fig. 6 produced greater errors. The contour lines developed sinusoidal-like oscillations over the entire flow field. For comparing these irregular contour levels a mean value between peaks in the oscillation was estimated and compared with the standard case. Again, the greatest error was found at the body surface. There was a 10% error in the positive Y-direction

that diminished rapidly around the rest of the body. Errors away from the body were negligible along the Y-axis, but were 6% along the X-axis.

2. Displaced Function

Figure 7, calculated in the same manner as Fig. 3, is the standard of comparison for the displaced cases. In Fig. 8 and Fig. 9, the center portions of the fringe array were, as before with the centered functions, replaced by INTRPL and by the linear interpolation, respectively.

A comparison of Fig. 7 with Fig. 8 showed slightly increasing errors over those of the centered cases. The greatest error occurred again where contour levels intersected the body. Errors in this region were from 7% to 12%, the higher error being associated with the higher contour levels. Elsewhere, there was good agreement between the two figures with the maximum error being on the order of 4%.

Figure 9 again produced sinusoidal-like oscillations. Using the same procedure discussed for Fig. 6, the maximum error was found to be about 5%. Again, as the contour lines neared the body, accuracy was lost. Errors had improved slightly in this region over the last comparison and were from 7% to 10%.

3. General Trends

Errors for the centered functions were found to be concentrated along the X-axis. Errors for the displaced functions were generally found in quadrant III. Flow fields

for both functions showed little error along the Y-axis. It should be noted that the Y-axis contained a discontinuity and a region of negative values.

The second method used to compare flows determined the number of grid points between like values of contrasted flows. The accuracy in the general location of contours from figure to figure was considered good. Contours locations differed by no more than two grid points.

III. CONCLUSIONS AND RECOMMENDATIONS

It has been demonstrated that fiber light guides can be applied to holographic interferometry. The experiment was rudimentary and requires refinement. The problems encountered in the course of the experiment involved accurate alignment of the pulsed laser beam and attenuation of energy associated with the fiber optics.

If more realistic experiments are to be conducted, longer fibers will possibly have to be used. Transmission losses of the order of 65% are associated with six-foot lengths of fibers. A means of coping with this high magnitude loss is needed.

The incomplete fringe information associated with the limited fields of view caused by an opaque body positioned in a flow field was tested using two methods of calculating data values for the blocked portion of the fringe array. Both methods provided fair estimates of the flows in the region near the surface of the body, but there was a general degradation of flow information over the entire flow region producing errors on the order of 5% to 10%.

In using the Fourier transformation method for fringe conversion given in Ref. 10, there is a degradation to the flow field due to the finite spacing of the grid points. This effect has not fully been investigated. Errors associated with the two schemes for creating fringe data

for blocked portions of the flow can compound the inherent errors of the basic program.

Further endeavors could be made in determining the effect on the investigation caused by differing the percentage of view that is blocked. The program could be run using a finer grid pattern or a greater number of views. These factors could all have an effect on flow errors.

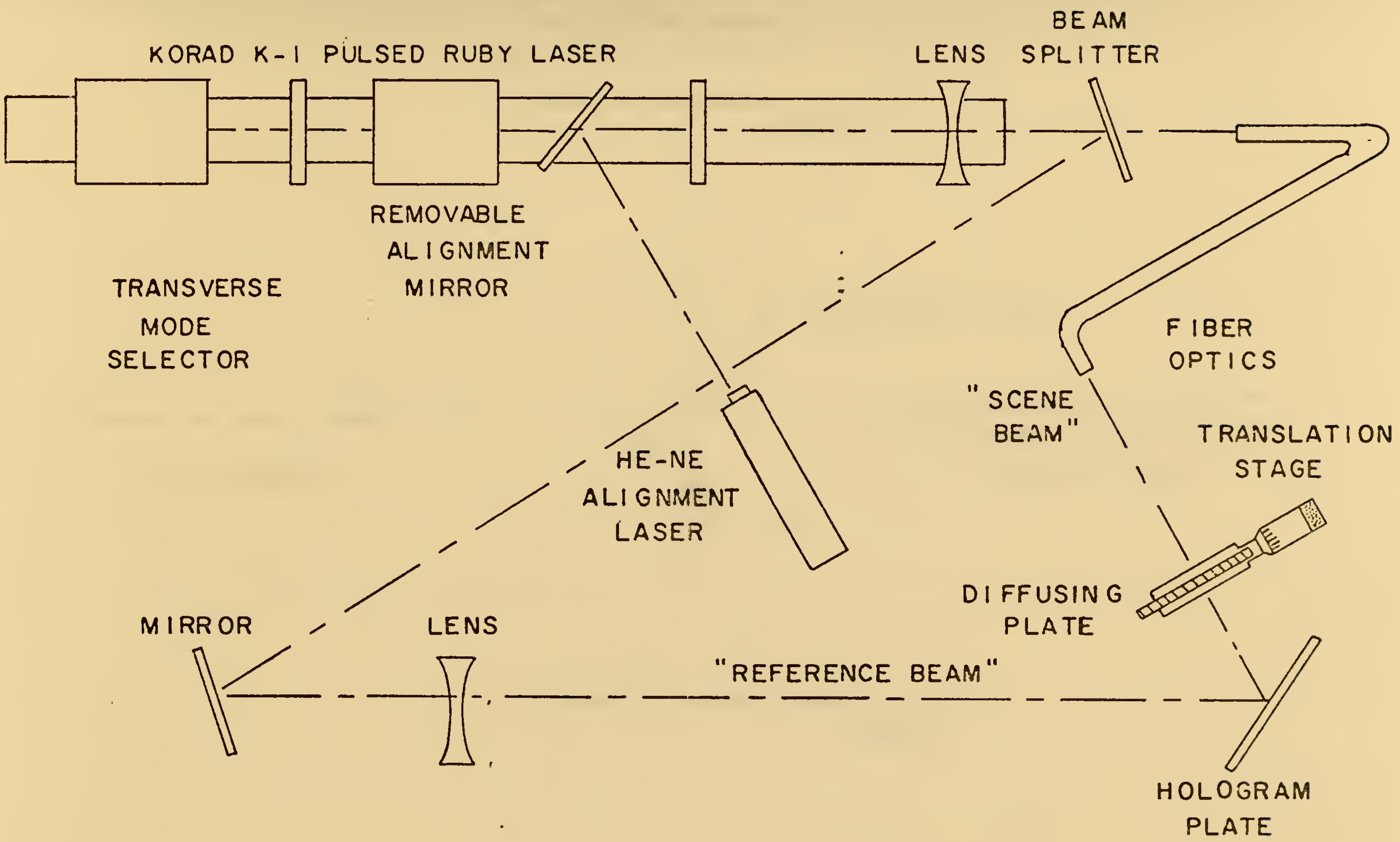

FIGURE 1. SCHEMATIC DRAWING OF THE HOLOGRAPHIC ARRANGEMENT

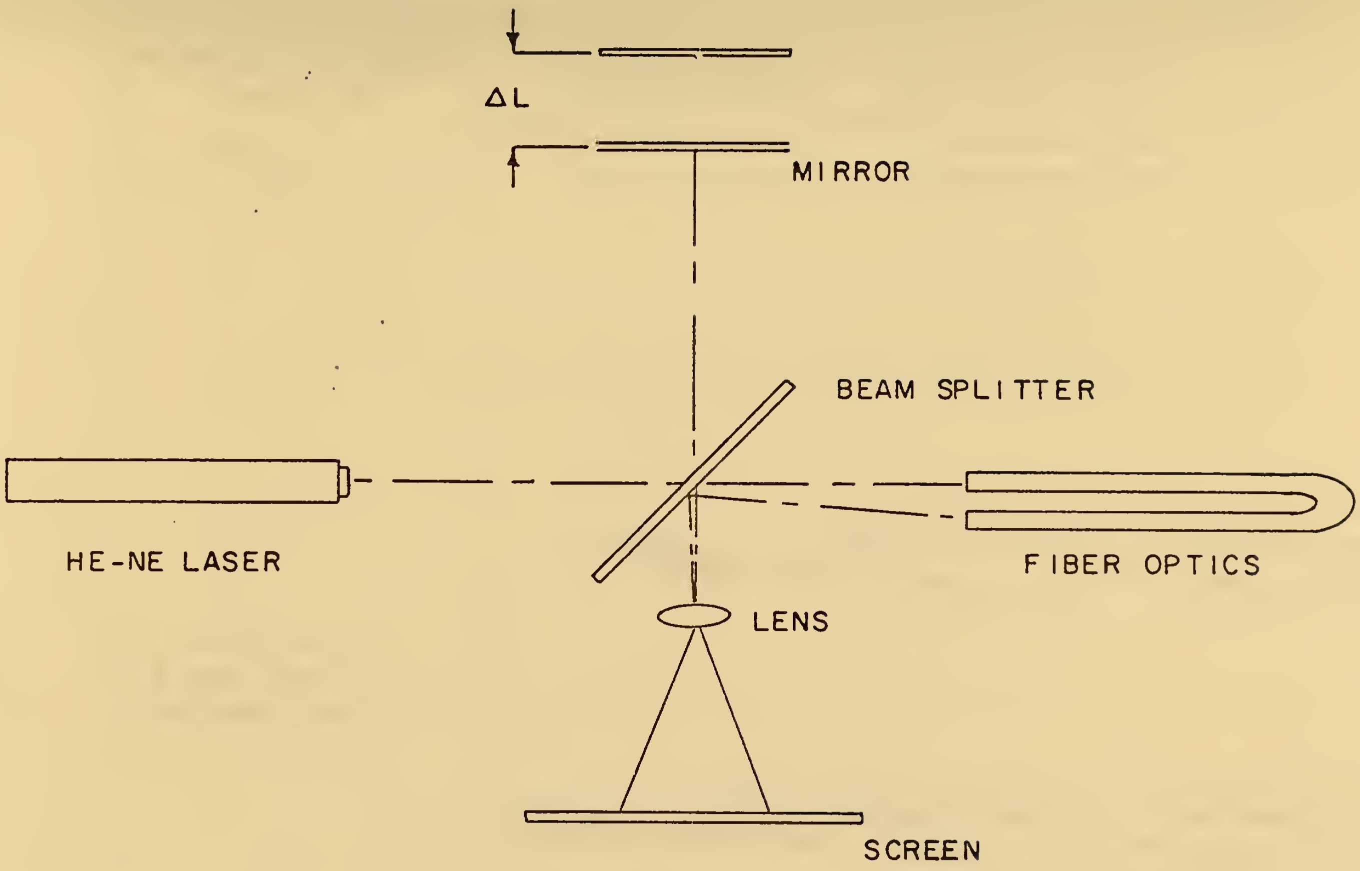

FIGURE 2. MICHELSON INTERFEROMETER WITH FIBER OPTICS

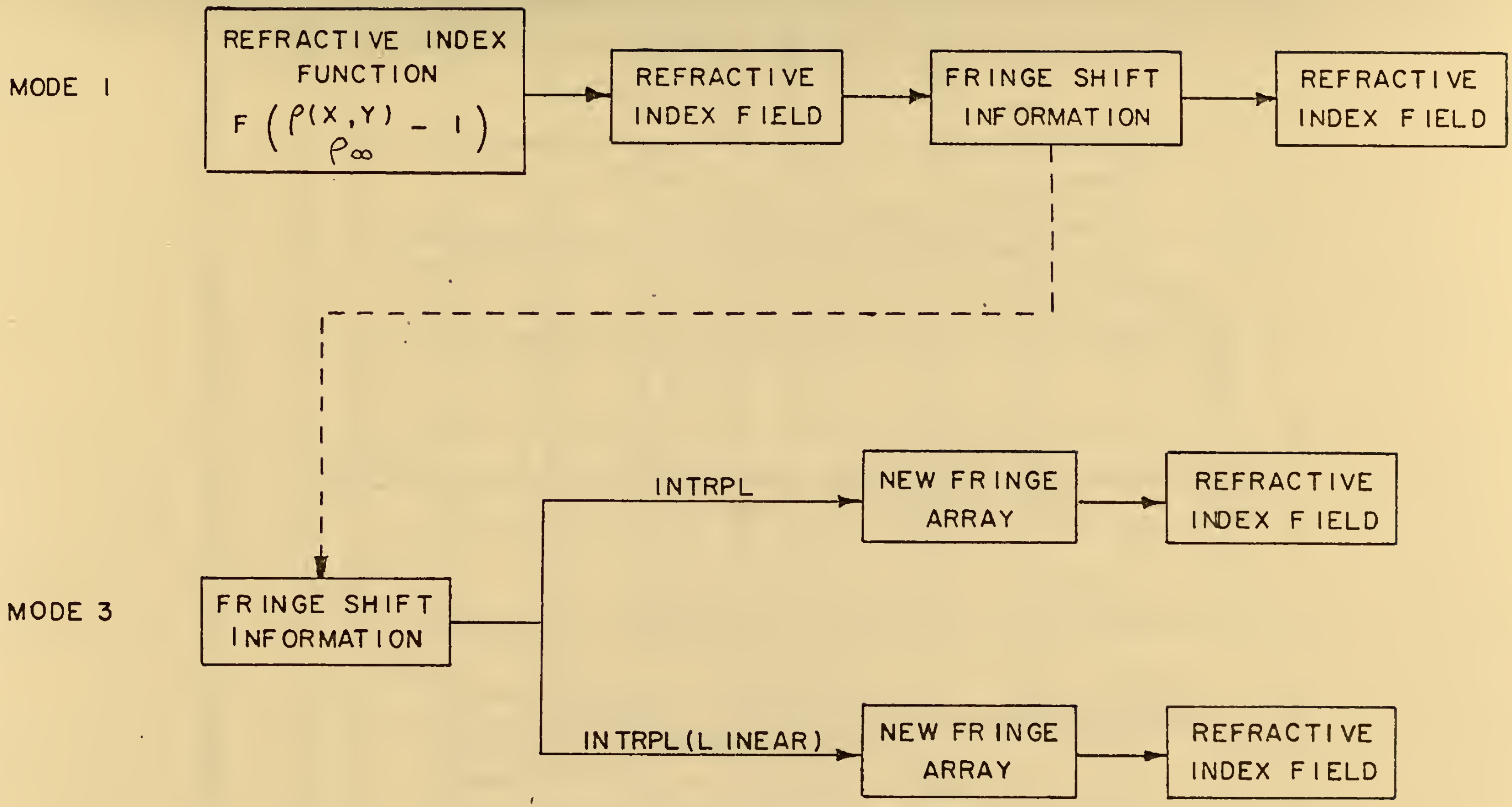

FIGURE 3. CALCULATION FLOW DIAGRAM

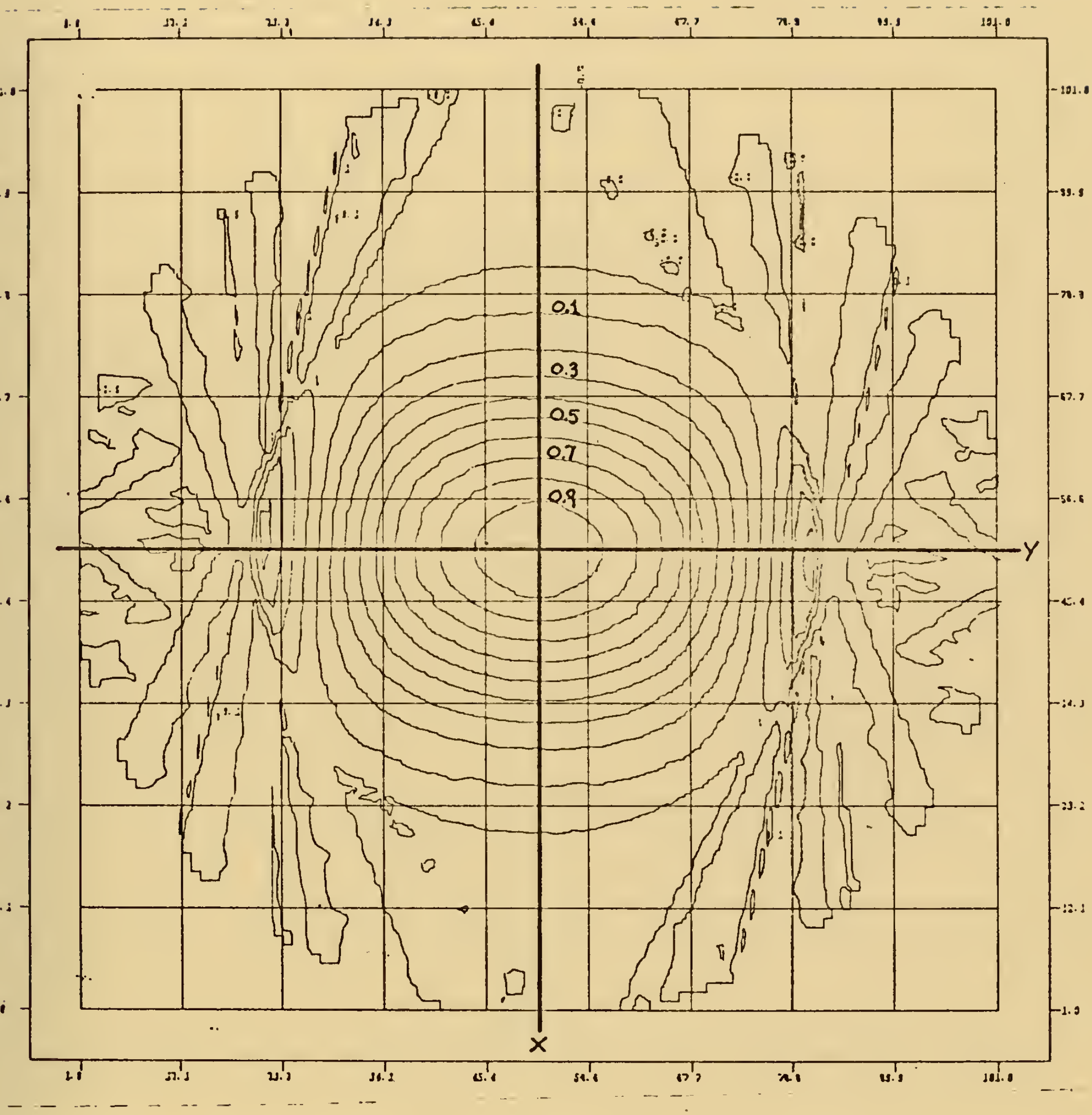

Figure 4. Standard Case for the Centered Function

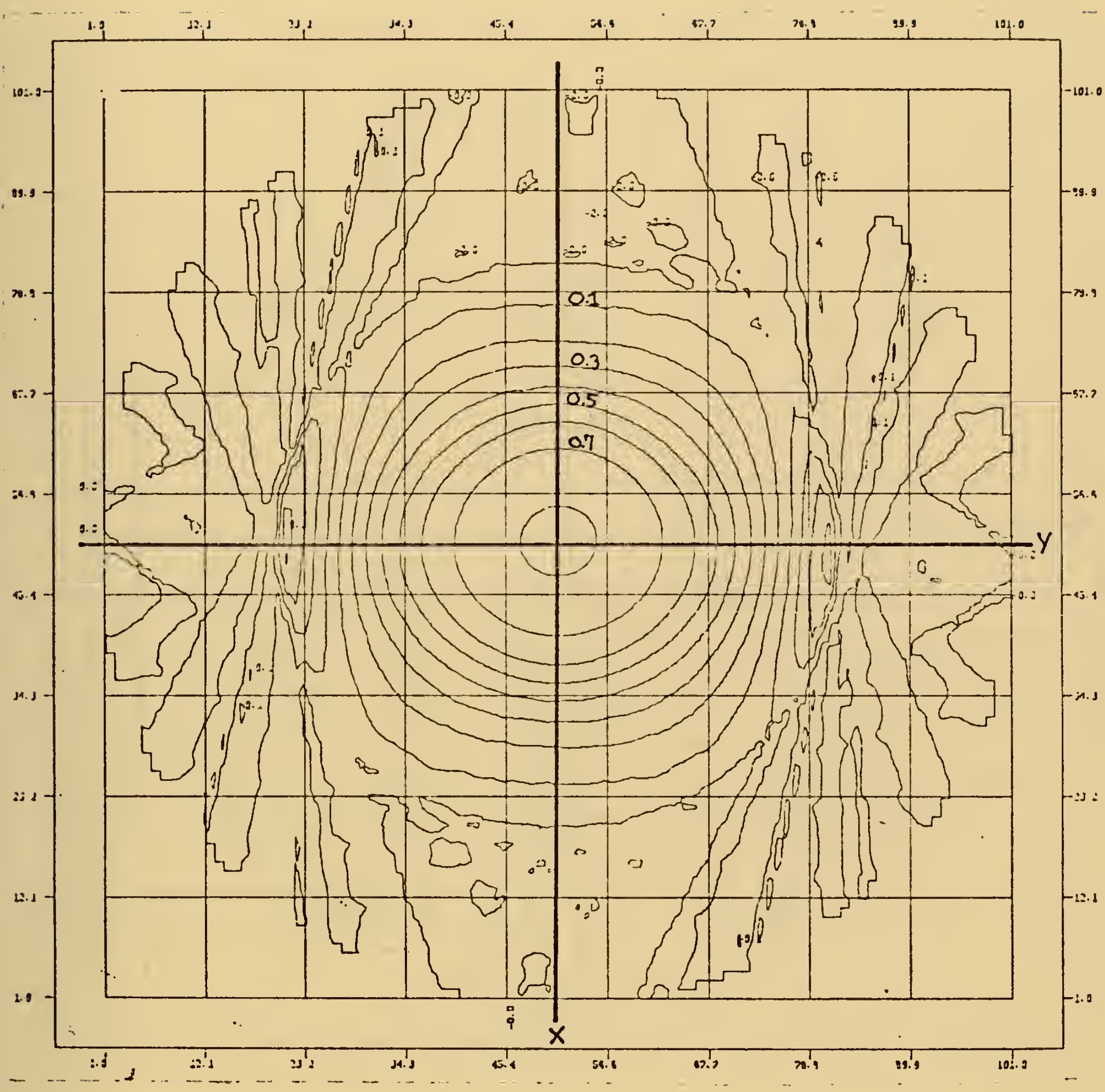

Figure 5. Centered Function Modified by INTRPL

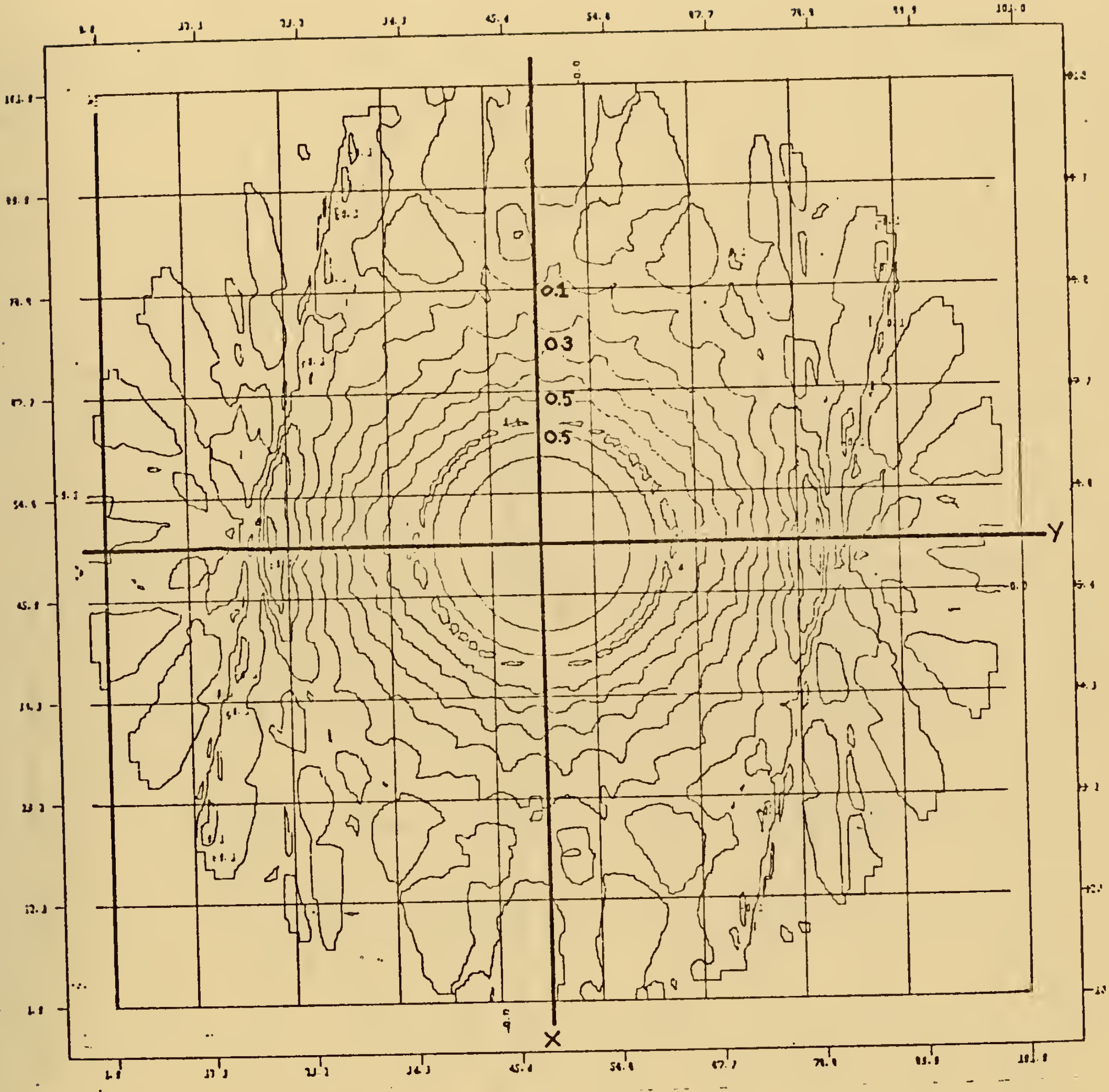

Figure 6. Centered Function Modified by INTRPL (LINEAR)

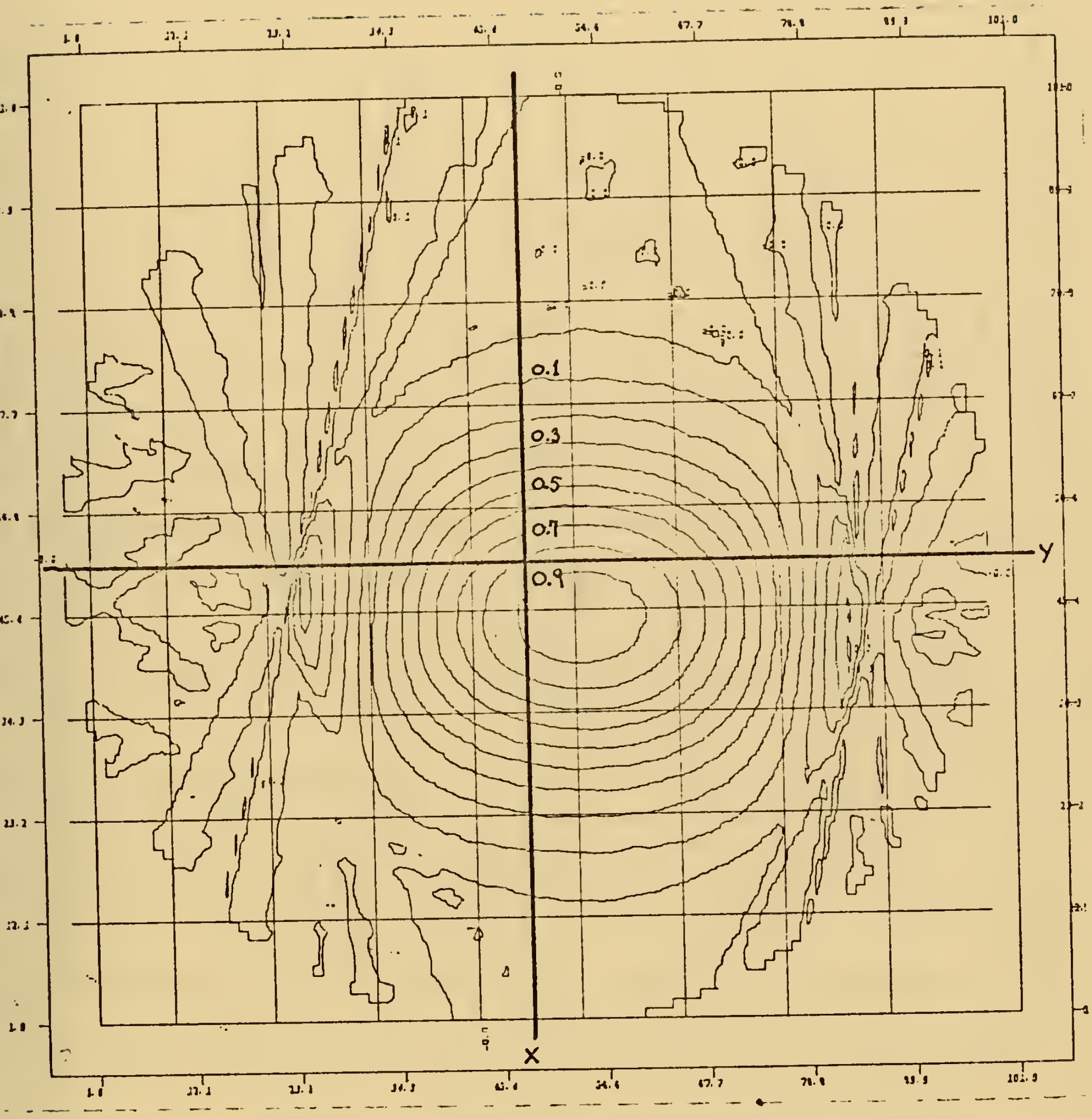

Figure 7. Standard Case for the Displaced Function

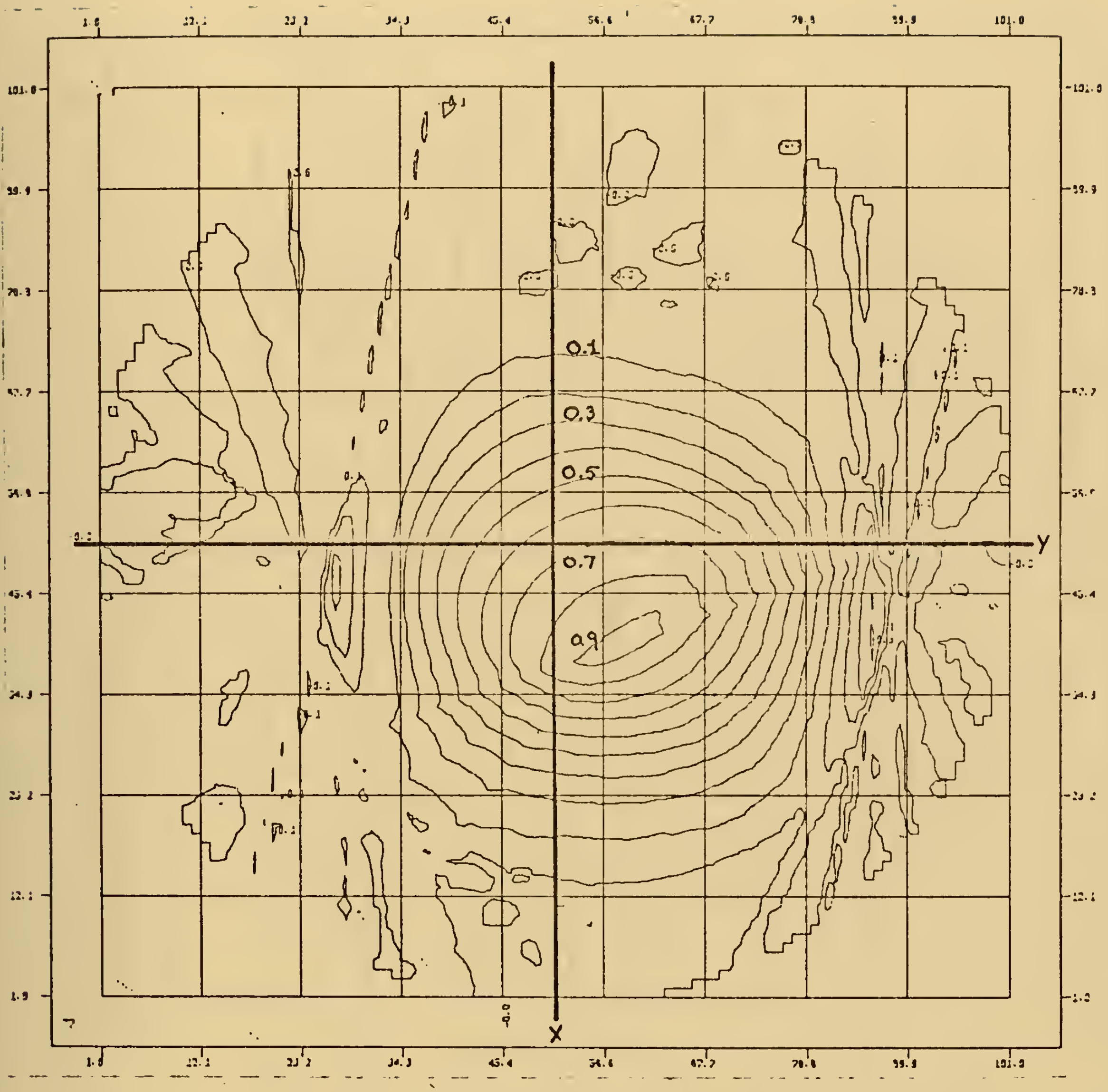

Figure 8. Displaced Function Modified by INTRPL

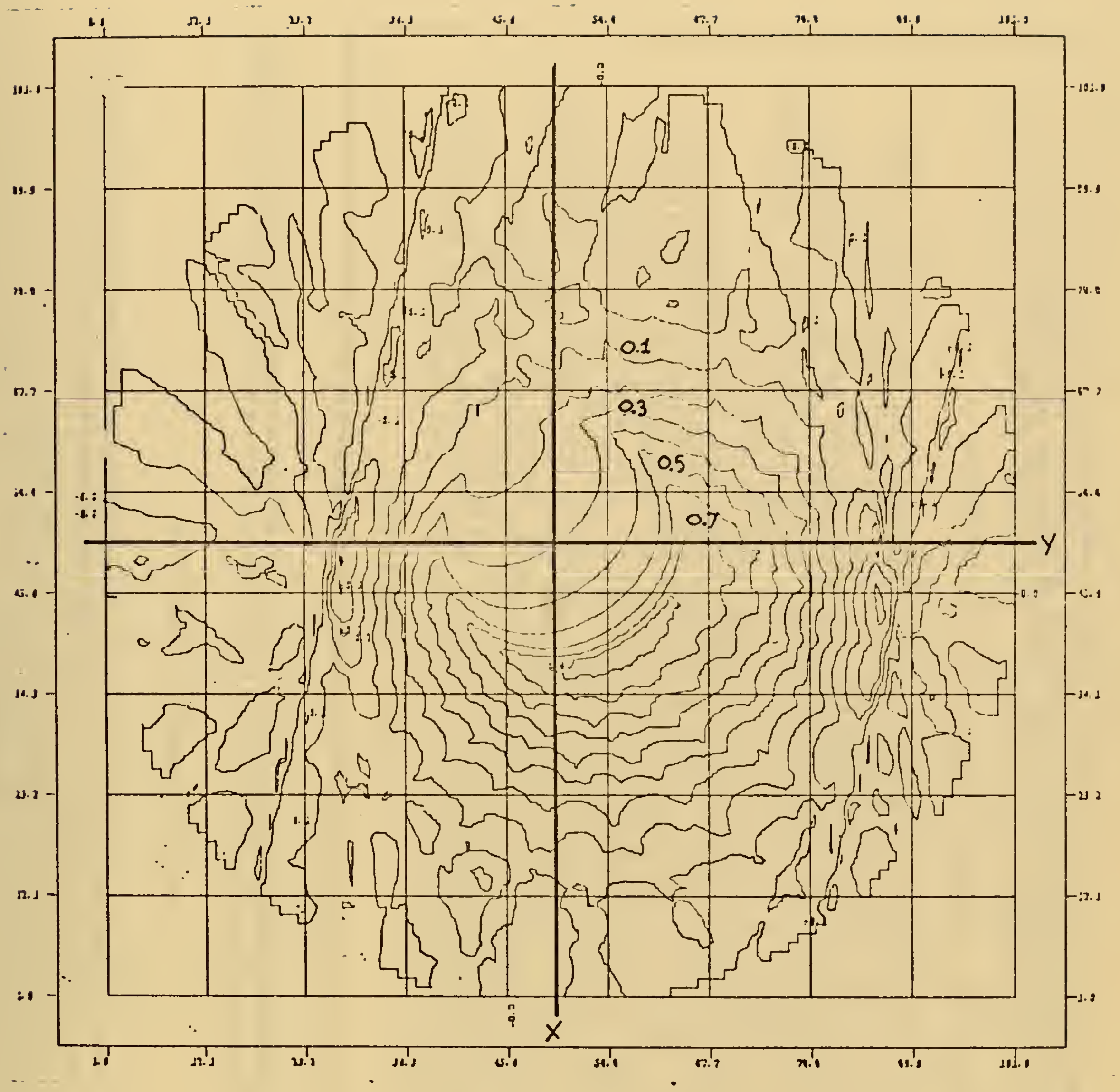

Figure 9. Displaced Function Modified by INTRPL (LINEAR)

APPENDIX A

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**********************************************************
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                   MAIN COMPUTER PROGRAM

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*                                                      *
*                INTEGRAL INVERSION                    *
*                                                      *
*  REFERENCE, THESIS BY P. E. VAN HOUTEN 'THE APPLICATION OF     *
*  HOLOGRAPHIC INTERFEROMETRY TO THE DETERMINATION OF DISCON-    *
*  TINUOUS THREE-DIMENSIONAL DENSITY FIELCS' 14 DEC 72            *
*      THE PROGRAM CONSIDERS A CIRCULAR REGION OF UNKNOWN        *
*  REFRACTIVE INDEX FOR WHICH THE TOTAL PHASE SHIFT(PATH LENGTH  *
*  DIFFERENCE) IS KNOWN FOR NUMEROUS RAYS AT REGULAR INTERVALS   *
*  FOR A GIVEN VIEWING ANGLE. THE PROGRAM REQUIRES NUMEROUS      *
*  VIEWS AT REGULARLY SPACED INTERVALS AND A TOTAL ANGULAR       *
*  COVERAGE OF 180 DEGREES(ASYMMETRIC). THE NECESSARY ANGULAR    *
*  COVERAGE IS REDUCED BY THE NUMBER OF DEGREES OF SYMMETRY.     *
*  BY THE USE OF TWO DIMENSIONAL FOURIER TRANSFORM TECHNIQUES    *
*  IT CAN BE SHOWN THAT  FOR A GIVEN POINT(X0,Y0) WITHIN THE     *
*  CIRCULAR REGION, THE DENSITY F(X0,Y0) CAN BE EXPRESSED IN     *
*  TERMS OF THE PHASE SHIFT INFORMATION G(R0,THETA).             *
*      IN ORDER TO SAVE COMPUTATION TIME, THE VALUE OF THE       *
*  INSIDE INTEGRATION IS COMPUTED AT EACH RAY POSITION FOR EACH  *
*  VIEWING ANGLE. FOR A GIVEN POINT(X0,Y0), THE VALUE OF THE     *
*  INSIDE INTEGRAL IS DETERMINED BY AVERAGING OVER A FINITE      *
*  PORTION OF A CUBIC POLYNOMIAL FITTED TO THE FOUR CLOSEST      *
*  VALUES OF THE INSIDE INTEGRAL.  THE INTEGRATION OVER THETA    *
*  USES THE TRAPEZOIDAL RULE.  THE INTEGRATION OVER RHO USES     *
*  COTES SIXTH ORDER QUADATURE FORMULA                           *
*                                                      *
*     MEANING OF SYMBOLS USED IN THE PROGRAM                     *
*                                                      *
*  IT(12)  TITLE USED FOR OUTPUT.  FIRST 48 CHARACTERS ON FIRST  *
*          DATA CARD, FIRST 16 CHARACTERS ON NEXT DATA CARD      *
*  RHOINF-DENSITY OUTSIDE REGION CF INTEREST IN MG/CC.           *
*  XLAMDA-WAVELENGTH OF MONOCHROMATIC,COHERENT LIGHT SOURCE IN   *
```

```
*  MICRONS.                                                          *
*  RHOINF AND XLAMDA ON THIRD DATA CARD IN (2F10.5) FORMAT           *
*  MODE      MODE=1  REFRACTIVE INDEX SUPPLIED THROUGH SUBROUTINE    *
*                    'INPUT'. THE PROGRAM GENERATES FRINGE DATA      *
*                    AND RECOMPUTES THE REFRACTIVE INDEX FROM        *
*                    THE GENERATED FRINGE DATA.                      *
*            MODE=2  REFRACTIVE INDEX SUPPLIED AT GRID PCINTS        *
*                    BY INPUT DATA. PROGRAM PROCEEDS AS IN MODE 1    *
*            MODE=3 FRINGE DATA SUPPLIED, PROGRAM GENERATES          *
*                   DENSITY FIELD.                                   *
*            MODE=4  SAME AS MODE=3 EXCEPT FRINGE DATA IS RECOM-     *
*                    PUTED AS PER MODE =2.                           *
*  NP  NUMBER OF EQUALLY SPACED DATA POINTS                          *
*  NT  NUMBER OF VIEWS SUPPLIED                                      *
*  KSYM  SYMMETRY OF FIELD  0-4 AXIS OF  SYMMETRY                    *
*                               4 -98  DATA REPEATS EVERY KSYM       *
*                                      DEGREES.                      *
*                               99 AXISYMETRIC FIELD                 *
*  RMAX  RADIUS OF CIRCULAR REGION  IN CENTIMETERS                   *
*  FILTER = (0.-1.) DETERMINES SPAN OVER WHICH AVERAGING OCCURS      *
*  THE ABOVE INFORMATION ON THE FOURTH DATA CARD(4I10,2F10.5).       *
*  X(I)   VECTOR OF GRID POINTS ALONG THETA = 0 DEGREES              *
*         X(1)=-RMAX     X(NP)=+RMAX                                 *
*  Y(J)   VECTOR OF GRID POINTS ALONG THETA=90 DEGREES               *
*         Y(1)=-RMAX   Y(NP)=+RMAX                                   *
*  A(I,J)   DENSITY OR REFRACTIVE INDEX AT THE POINT X(I),Y(J).      *
*  RB(I) VECTOR OF POINTS ON THE HCLOGRAPHIC PLATE RB(1)=-2 RMAX     *
*  RB(2 NP)=2 RMAX.        -                                         *
*  DR   SPACING OF GRID,SPACING OF RAYS.  DR=2*RMAX/(NP-1)           *
*  TH(K)   VECTOR OF VIEWING ANGLES  IN DEGREES                      *
*  B(I,K)   FRINGE SHIFT INFORMATION AT THE POINT(RB(I),TH(K)).      *
*  B(I,K) IS COPIED INTO BB(I,K). THE VALUE OF THE INSIDE            *
*  INTEGRATION IS THEN STORED IN B(I,K).                             *
*  DASYM(K) SYMMETRY OF DATA(B(I,K). 0 NC SYMETRY                    *
*                                    1 DATA SYMETRIC ABOUT RB=0.     *
*  IF DASYM = 1.0 ONLY (NP+1)/2 DATA POINTS SHOULD BE FURNISHED.     *
*  BD(L) IS A WORK VECTOR USED BY THE PROGRAM.                       *
*  FOR MODE=1 OR  MODE=2 THE FIFTH DATA CARC IS THE VECTOR           *
*  TH(K) IN (8F10.5) FORMAT                                          *
*  FCR MODE 2 OPERATION THE REFRACTIVE INDEX FOLLOWS IN 8F10.5       *
*  FORMAT.                                                           *
*  FOR MODE=3 AND MODE=4 OPERATION, THE FIFTH DATA CARD IS           *
*  TH(1) AND DASYM(1) IN (2F10.5) FORMAT.  THIS IS FOLLOWED          *
*  BY THE FRINGE INFORMATION FOR THAT VIEW (B(I,1) ETC UNTIL         *
*  ALL VIEWS AND FRINGE SHIFT HAS BEEN SUPPLIED                      *
*  IF AXIS OF SYMMETRY EXISTS,THETA=0. MUST CORRESPOND TO ONE OF     *
*  THE AXIS OF SYMMETRY.                                             *
*                                                                    *
```

```
      ***********************************************************************
      REAL*8 IT(12),LAB,ITSUB(12)/'REFRACTIVE INCEXDENSITY IN MG/CC     T
     1HETA=  ODEG     THETA= 90DEG     THETA= 45DEG     THETA=-45DEG'/
      REAL*8 ITT(12)
      DIMENSION CL(18)
      DIMENSION X(101),Y(101),A(101,101),B(101,20),BD(811),TH(36),
     1BB(301,20),RB(301),DASYM(20),SS(36),CC(36)
      LOGICAL*1 LTG(3)
      F1(AA,BD,CC,RR)=CC+RR*(BD+RR*(AA))
      DATA NL,IW,IH/18,9,9/
      DATA C1,C2,C3,C4/.2292857,1.54285,.192857,1.94285/,LAB/'        '/
      DATA NMAP/2/
  109 FORMAT('0','NMAP=',I3)
  100 FORMAT (4I10,2F10.5)
  101 FORMAT('0',T20,'  MODE      NUM PTS  NUM VIEWS   KSYM   RADIUS
     1GRID SPACING  FILTER')
  102 FORMAT('0',T17,4I10,3F10.5)
  103 FORMAT(8F10.5)
  104 FORMAT('0',T7,20F6.1//)
  105 FORMAT('0',F5.2,20F6.2)
  106 FORMAT('0',//)
  107 FORMAT('0',T9,'MODE 1',T26,'MODE 3',T45,'VALUE'/,T9,'GIVEN    COMP
     1     DENSITY',T47,'OF'/,'RADIUS  REFRAC   REFRAC  FIELD     FRINGE
     2  INSIDE'/,'  CM    INDEX    INDEX   MG/CC     SHIFT    INTEGRAL'
     3//)
  108 FORMAT('0',T20,'RHCINF =',F7.5,' MG/CC  LAMDA=',F7.5,' MICRONS')
  110 FORMAT('1',T7,21F6.2//)
  111 FORMAT('0',F5.2,1X,21F6.2)
  112 FORMAT(6A8)
  113 FORMAT(' ',T40,'Y AXIS(THETA=90 DEGREES) VERTICAL'/,T40,
     1'X AXIS(THETA = 0 DEGREES) HORIZONTAL'//)
  114 FORMAT('0',T40,'DENSITY FIELD IN MG/CC FCLLCWS')
  115 FORMAT('0',T40,'INDEX OF REFRACTICN FOLLOWS')
  116 FORMAT('1','THE EXPANDED FRINGE SHIFT INFORMATION IS AS FOLLOWS'/)
  117 FORMAT('1','THE VALUE OF THE INSIDE INTEGRATION IS AS FOLLOWS'//)
  118 FORMAT(10F7.4)
      DO 75 KXX=1,6
      NMAP=NMAP+1
      DO 120 I=2,19
      CL(1)=-0.8
      K=I-1
  120 CL(I)=CL(1)+K*0.10
      DO 121 I=1,3
      LTG(I)=.TRUE.
  121 CONTINUE
      READ(5,112) (IT(I),I=1,12)
      READ(5,112)(ITT(I),I=1,12)
      READ(5,103) RHOINF,XLAMD
```

```
      READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
      WRITE(6,106)
      WRITE(6,109) NMAP
      WRITE(6,112)(ITT(I),I=1,12)
      WRITE(6,108) RHOINF,XLAMD
      FNP=FLOAT(NP)
      DR=2.*RMAX/(FNP-1)
      WRITE(6,101)
      WRITE(6,102) MODE,NP,NT,KSYM,RMAX,DR,FILTER
      N=(NP+1)/2
      NPL=(NP-1)/2
      NPP=2*NP-1
      MAX=NP+NPL
      RM2=RMAX**2
      NP5=3*NP-2
      FNP5=FLOAT(NP5)
      NPM1=NP-1
      FT2=FILTER*FILTER

*****ZERO MATRICES AND SET GRID **************************************

      DO 2 I=1,NP
      DO 1 J=1,NP
    1 A(I,J)=0.0
      DO 2 K=1,NT
    2 B(I,K)=0.0
      X(1)=-RMAX
      Y(1)=X(1)
      DO 3 I=2,NP
      X(I)=X(I-1)+DR
    3 Y(I)=X(I)

***********************************************************************
      GO TO (4,4,29,29),MODE

*****READ VIEWING ANGLES AND SET SIN AND COSINE FOR MODE=1,2**********

    4 READ(5,103) (TH(K),K=1,NT)
      DC 5 K=1,NT
      THETA=TH(K)/57.296
      CC(K)=COS(THETA)
    5 SS(K)=SIN(THETA)

**********************************************************************

      IF(MODE.EQ.1) GO TO 7

*****READ REFRACTIVE INDEX FOR MODE=2 OPERATION***********************
```

```
      DO 6 I=1,NP
    6 READ(5,103)(A(I,J),J=1,NP)
***********************************************************************

      GO TO 9
    7 IF(KSYM.EQ.99) GO TO 13

*****SET REFRACTIVE INDEX AND WRITE SAME FOR MODE ONE OPERATION*******

      DO 8 I=1,NP
      DO 8 J=1,NP
      XI=X(I)
      YJ=Y(J)
      CALL INPUT(XI,YJ,VAL)
    8 A(I,J)=VAL
    9 WRITE(6,115)
      WRITE(6,113)
      K=1
      K21=21
   11 WRITE(6,106)
      WRITE(6,110) (X(I),I=K,K21)
      DO 12 I=1,NP
      NN=NP-I+1
   12 WRITE(6,111) Y(NN),(A(J,NN),J=K,K21)
      IF(K21.EQ.NP) GO TO 150
      K=K21+1
      K21=K21+21
      IF(K21.GT.NP) K21=NP
      GO TO 11
  150 A(1,1)=-1.0
      A(1,2)=1.0

      CALL CTRMAP(A,NMAP,NP,NP)
      WRITE(6,112)(ITT(I),I=1,12)
      CALL CONTUR(A,NP,NP,101,CL,NL,ITT,IW,IH,LTG)
      GO TO 15
***********************************************************************

*****SET REFRACTIVE INDEX FOR AXISYMETRIC CASE*************************

   13 DO 14 I=1,NP
   14 CALL INPUT(X(I),0,A(I,N))

***********************************************************************

   15 IF(MODE.EQ.2) GO TO 19
```

```
*****INTEGRATE FOR FINGE SHIFT FOR MODE ONE CASE**********************

     DO 18 K=1,NT
     R=-RMAX
     B(1,K)=0.0
     B(NP,K)=0.0
     DO 18 I=2,NPM1
     R=R+DR
     P1=SQRT(RM2-R**2)
     DP=2.*P1/FNP5
     P=-P1
     DO 16 J=1,NP5
     YJ=R*CC(K)+P*SS(K)
     XI=-R*SS(K)+P*CC(K)
     CALL INPUT(XI,YJ,VAL)
     P=P+DP
  16 BD(J)=VAL
     SUM=0.
     NPP2=NP5-2
     DC 17 J=1,NPP2,2
*****INTEGRATION USES SIMPSON'S RULE **********************
  17 SUM=SUM+BD(J)+4.*BD(J+1)+BD(J+2)
  18 B(I,K)=SUM*DP/3.
     GO TO 34

**********************************************************************

*****INTEGRATE FOR FINGE SHIFT FOR MODE TWO CASE**********************

  19 K=0
  20 K=K+1
     IF(K.GT.NT) GO TO 33
     IF(TH(K).EQ.0.) GO TO 23
     IF(TH(K).EQ.90.) GO TO 26
     R=-RMAX
     B(1,K)=0.0
     B(NP,K)=0.0
     DO 22 L=2,NPM1
     SUM=0.
     R=R+DR
     P1=SQRT(RM2-R**2)
     DP=2.*P1/FNP5
     P=-P1
     DO 21 LL=1,NP5
     XN=-R*SS(K)+P*CC(K)
     YN=R*CC(K)+P*SS(K)
     LINEAR INTERPOLATE FOR VALUE OF REFRACTIVE INDEX*****
```

```
      I=(XN+RMAX+DR)/DR
      J=(YN+RMAX+DR)/DR
      XD=(XN-X(I))/DR
      YD=(YN-Y(J))/DR
      VAL=A(I,J)+XD*(A(I+1,J)-A(I,J))
      VAL=VAL+YD*(A(I,J+1)+XD*(A(I+1,J+1)-A(I,J+1))-VAL)
      *****************************************************
      SUM=SUM+VAL*DP
  21  P=P+DP
  22  B(L,K)=SUM
      GO TO 20
  23  DO 25 J=1,NP
      B(J,K)=0.0
      DO 24 I=2,NP
  24  B(J,K)=B(J,K)+ (A(I-1,J)+A(I,J))
  25  B(J,K)=DR*B(J,K)/2.
      GO TO 20
  26  DO 28 I=1,NP
      L=NP+1-I
      B(L,K)=0.0
      DO 27 J=2,NP
  27  B(L,K)=B(L,K)+A(I,J-1)+A(I,J)
  28  B(L,K)=DR*B(L,K)/2.
      GO TO 20

**********************************************************************

*****READ DATA FOR MODE THREE OR FOUR OPERATION***********************

  29  DO 32 I=1,NT
      READ(5,103) TH(I),DASYM(I)
      IF(DASYM(I).EQ.1.) GO TO 30
      READ(5,103) (B(J,I),J=1,NP)
      GO TO 32
      READ AND COPY SYMETRIC DATA *************************
  30  READ(5,103) (B(J,I),J=1,N)
      L=N+1
      DO 31 J=L,NP
      K=NP-J+1
  31  B(J,I)=B(K,I)
      *****************************************************
  32  CONTINUE

**********************************************************************

  33  IF(MODE.EQ.5) GO TO 63
```

```
*****SET RADIUS VECTOR AND EXTEND FRINGE INFORMATION TO TWICE RMAX****

   34 RB(1)=-2.*RMAX
      DO 35 I=2,NPP
   35 RB(I)=RB(I-1)+DR
      DO 38 I=1,NT
      Q1=B(1,I)
      Q2=(B(2,I)-B(1,I))/DR
      CALL COEF(Q1,Q2,-RMAX,E,G,C)
      DO 36 J=1,NPL
   36 BB(J,I)=F1(E,G ,C,RB(J))
      DO 37 K=1,NP
   37 BB(K+NPL,I)=B(K,I)
      Q1=B(NP,I)
      Q2=(B(NP,I)-B(NP-1,I))/DR
      CALL COEF(Q1,Q2, RMAX,E,G,C)
      L=NP+NPL
      DO 38 K=L,NPP
   38 BB(K,I)=F1(E,G ,C,RB(K))

** *********************************************************************


*****CALCULATE VALUE OF INSIDE INTEGRAL *******************************

      DO 43 I=1,NT
      DC 43 J=1,NP
      M=NPL+J
      BD(1)=0.
      DO 39 K=1,MAX
      MKP=M+K
      MKM=M-K
      IF(MKP.GT.NPP) MKP=NPP
      IF(MKM.LT.1) MKM=1
      K1=K**2
   39 BC(K+1)=(BB(MKP,I)+BB(MKM,I)-2.*BB(M,I))/(FLOAT(K1)*DR)
      VAL=0.
      K1=1
   40 K2=K1+6
      IF(K2.GT.MAX) GO TO 41
      COTES SIXTH ORDER QUADATURE FORMULA******************
      VAL=VAL+C1*(BD(K1)+BD(K2))+C2*(BC(K1+1)+BD(K2-1))+C3*(BD(K1+2)+BD(
     1K2-2))+C4*BD(K1+3)
      K1=K2
      GC TO 40
   41 SUM=0.
      CCNTRIBUTION OF LAST TERMS
      DO 42 K=K1,MAX
```

```
   42 SUM=SUM+BD(K)+BD(K+1)
      SUM COTES PLUS LAST TERMS PLUS INTEGRATION FROM 2 RMAX TO INFINITY
   43 B(J,I)= VAL+SUM/2.-.666667*BB(M,I)/RMAX
      IF(KSYM.LT.99) GO TO 48

*************************************************************************


*****INTEGRATE OVER THETA FOR AXISYMETRIC CASE************************

      DEL=-.004421
      M=1
      TH(1)=0.0
      SS(1)=0.0
      DO 44 I=2,19
      TH(I)=TH(I-1)+5.
   44 SS(I)=SIN(TH(I)/59.296)
      WRITE(6,107)
      DO 47 I=1,NP
      DO 45 K=1,19
      R=-X(I)*SS(K)
      L=(R+RMAX+DR)/DR
      IF(L.GE.NP) GO TO 460
      IF(L.LT.1) GO TO 460
      LP2=L+2
      LP1=L+1
      LM1=L-1
      IF(LP2.GT.NP) LP2=NP
      IF(LM1.LT.1) LM1=1
      P=(R-X(L))/DR
      COF3=.1666666*(B(LP2,K)-B(LM1,K))-.5*(B(LP1,K)-B(L,K))
      COF2=.5*(B(LP1,K)+B(LM1,K))-B(L,K)
      CCF1=-.1666666*B(LP2,K)+B(LP1,K)-.333333*B(LM1,K)-.5*B(L,K)
      P2=P*P
*****AMOUNT OF FILTERING DEPENDS ON FT2=FILTER*FILTER*********
   45 BD(K)=P*(P2+FT2)*COF3+(P2+.666666*FT2)*COF2+P*COF1+B(L,K)
      SUM=0.0
      TRAPEZOIDAL INTEGRATION ON THETA    *****************
      DC 46 K=2,19
      SUM=SUM+BD(K)+BD(K-1)
   46 CONTINUE
      A(I,1)=SUM*DEL
  460 CONTINUE
      OUTPUT IS DENSITY FIELD IF MODE=3******************
      IF(MODE.LT.3) GO TO 47
      A(I,2)=RHOINF+.4443*XLAMD*A(I,1)
   47 WRITE(6,105) X(I),A(I,N),A(I,1),A(I,2),BB(NPL+I,1),B(I,1)
```

```
**********************************************************************
      IF(MODE.LT.3) GO TO 75
      GO TO 75
   48 M=NT+1
      IF(KSYM.EQ.0) GO TO 51
      IF(KSYM.GT.4) GO TO 53

*****GENERATE ADDITIONAL DATA DEPENDING ON SYMETRY OF FIELD***********

      DT=TH(2)-TH(1)
      NTP=NT
      DC 50 J=1,KSYM
      K=J*NT
      DO 49 I=1,NTP
      KK=K+I
      TH(KK)=TH(KK-1)+DT
      KM=K-I+1
      DC 49 L=1,NP
   49 B(L,KK)=B(L,KM)
   50 NTP=2*NTP
      M=KK+1

**********************************************************************
*****GENERATE DATA FOR 180 DEGREE VIEW********************************

   51 TH(M)=TH(1)+180.
      DO 52 I=1,NP
      K=(NP-I+1)
   52 B(K,M)=B(I,1)

**********************************************************************

      GC TO 55

*****GENERATE ADDITIONAL DATA FOR REPEATING DATA**********************

   53 M=180/KSYM+1
      DO 54 I=2,M
      TH(I)=TH(I-1)+FLOAT(KSYM)
      DC 54 J=1,NP
   54 B(J,I)=B(J,I-1)
   55 CONTINUE

**********************************************************************
```

```
*****INTEGRATE ON THETA FOR ASYMETRIC FIELD***************************

      MD=M-1
      DEL=-1./(2.*3.1416*FLOAT(MD))
      DO 56 I=1,M
      CC(I)=COS(TH(I)/59.296)
   56 SS(I)=SIN(TH(I)/59.296)
      DO 61 LL= 1,NP
      J=NP+ 1-LL
      DC 60 I= 1,NP
      A(I,J)=0.
      DC 58 K=1,M
      R=Y(J)*CC(K)-X(I)*SS(K)
      NN=(R+RMAX+DR)/DR
      IF(NN.GE.NP) GO TO 60
      IF(NN.LT.1) GO TO 60
      LP2=NN+2
      LP1=NN+1
      LM1=NN-1
      IF(LP2.GT.NP) LP2=NP
      IF(LM1.LT.1) LM1=1
      P=(R-X(NN))/DR
      COF3=.1666666*(B(LP2,K)-B(LM1,K))-.5*(B(LP1,K)-B(NN,K))
      COF2=.5*(B(LP1,K)+B(LM1,K))-B(NN,K)
      CCF1=-.1666666*B(LP2,K)+B(LP1,K)-.333333*B(LM1,K)-.5*B(NN,K)
      P2=P*P
*****AMCUNT OF FILTERING DEPENDS ON FT2=FILTER*FILTER**********
   58 BD(K)=P*(P2+FT2)*COF3+(P2+.666666*FT2)*COF2+P*COF1+B(NN,K)
      INTEGRATE OVER THETA USING TRAPEZOIDAL INTEGRATION*********
      VAL=0.0
      DO 59 L=2,M
   59 VAL=VAL+BD(L)+BD(L-1)
      A(I,J)=VAL*DEL/2.
****************************************************************
   60 CONTINUE
   61 CCNTINUE

**********************************************************************

      NFN=NP+NPL
      IF(MODE.LT.4) GO TO 63
      IF(MODE.EQ.4) MODE=5
      GO TO 19
   63 IF(MODE.LT.3) GO TO 65

*****CHANGE REFRACTIVE INDEX FIELD TO DENSITY FIELD*******************
```

```
  65 WRITE(6,115)
  66 WRITE(6,113)

*****WRITE REFRACTIVE INDEX OR DENSITY FIELD***************************

     K=1
     K21=21
  67 WRITE(6,106)
     WRITE(6,110) (X(I),I=K,K21)
     DO 68 I= 1,NP
     NN=NP-I+1
  68 WRITE(6,111) Y(NN),(A(J,NN),J=K,K21)
     IF(K21.EQ.NP) GO TO 690
     K=K21+1
     K21=K21+21
     IF(K21.GT.NP) K21=NP
     GC TO 67
***********************************************************************


 69C A(1,1)=-1.0
     A(1,2)=1.0
     CALL CTRMAP(A,NMAP,NP,NP)
     WRITE(6,112)(ITT(I),I=1,12)
     CALL CONTUR(A,NP,NP,101,CL,NL,ITT,IW,IH,LTG)

  69 WRITE(6,116)

*****WRITE FRINGE SHIFT INFORMATION************************************

     WRITE(6,104) (TH(K),K=1,NT)
     DC 70 I=N,NPN
  7C WRITE(6,105) RB(I),(BB(I,J),J=1,NT)
     WRITE(6,112)(ITT(I),I=1,12)


     WRITE(6,116)
     WRITE(6,104) (TH(K),K=1,NT)
     DO 700 J=1,NT
     WRITE(6,103) TH(J)
     WRITE(6,103)(BB(I,J),I=N,NPN)
 70C CONTINUE
```

```
      WRITE(7,112)(IT(I),I=1,12)
      WRITE(7,103) RHOINF,XLAMD
      WRITE(7,100) MODE,NP,NT,KSYM,RMAX,FILTER
      DO 710 J=1,NT
      WRITE(7,103) TH(J)
      WRITE(7,103)(BB(I,J),I=N,NPN)
  710 CONTINUE

      WRITE(6,117)
      WRITE(6,104) (TH(K),K=1,M)
      DO 71 I=1,NP
   71 WRITE(6,105) X(I),(B(I,J),J=1,M)
      WRITE(6,112)(ITT(I),I=1,12)

   75 CONTINUE
      STOP
      END

      SUBROUTINE COEF(VAL,SLOPE,U,CU2,CU,CONST)
      *****************************************************************
      *                                                               *
      *  SUBROUTINE COEF CALCULATES THE COEFICIENTS USED BY  THE      *
      *  FUNCTION (F1) TO EXPAND THE FRINGE INFORMATION TO 2 RMAX     *
      *                                                               *
      *****************************************************************
      U2=U*U
      CU2=-SLOPE/U-VAL/U2
      CU=-VAL/U-3.*U*CU2
      CONST=VAL-CU*U-CU2*U2
      RETURN
      END

      SUBROUTINE INPUT(XI,YJ,VAL)
      *****************************************************************
      *                                                               *
      *  SUBROUTINE INPUT IS SUPPLIED BY THE USER FOR MODE 1          *
      *  OPERATION.  THE MAIN PROGRAM PASSES THE POINT (XI,YJ) AND    *
      *  'INPUT' SUPPLIES THE VALUE OF THE REFRACTIVE INDEX AT THAT   *
      *  POINT USING ANY ARITHMETIC OR LOGIC STATMENT NECESSARY.      *
      *                                                               *
     *****************************************************************
      VAL=0.
      VAL=F(XI,YJ)
      RETURN
      END
```

```
*********************************************************************
    *                                                               *
    *   THE INPUT DATA FILES USED IN THE TESTING ARE INCLCDED       *
    *                                                               *
*********************************************************************


                    CASE #1
       THE ASYMMETRIC TEST CASE CF FIGURE 8
     RUN UNDER MODE 1
     Y2=YJ*YJ
     X2=XI*XI
     VAL=(1.-Y2)*EXP(-2.*X2)
     R2=Y2+X2
     IF(R2.GT.1.5) VAL = 0.
     RETURN
     END
*********************************************************************
     NECESSARY DATA CARDS
*********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE CN (Y)
     MCDE 1 STANDARD CASE
     CASE #1
 1.176     .6941
        1       101         6         1      2.0       .5
   07.5      22.5      37.5      52.5      67.5      82.5
*********************************************************************
*********************************************************************


                    CASE #3
       THE ASYMMETRIC TEST'CASE OF FIGURE 8
     RUN UNDER MODE 3
*********************************************************************
     NECESSARY DATA CARDS
*********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE CN (Y)
EVERETT INTRPL OF FIGURE #8
     CASE #3
 1.176     .6941
                                          KSYM    RMAX       Filter
     mode 3    NP 101        NT 6            1   2.0000C   0.50000
********************************************************************
     CONTINUE ENTERING FRINGE SHIFT INFORMATION
               OBTAINED FROM CASE #1
********************************************************************
```

```
          THE MODIFIED OUTPUT FRINGE SHIFT INFORMATICN
                         FOR THIS CASE IS:
*******************************************************************************
TH(I) 7.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0       -0.18822   -0.22693   -0.20304   -0.15116
-0.08012   -0.00176    0.08060    0.16530    0.24902    0.33243    0.41315    0.49143
 0.56688    0.63918    0.70646    0.77017    0.83009    0.88627    0.93691    0.98347
 1.02598    1.06442    1.09881    1.12914    1.15541    1.17762    1.19578    1.20989
 1.21996    1.22597    1.22794    1.22587    1.21975    1.20959    1.19540    1.17717
 1.15491    1.12861    1.09828    1.06392    1.02553    0.98312    0.93669    0.88623
 0.83013    0.77014    0.70649    0.63918    0.56691    0.49149    0.41325    0.33258
 0.24880    0.16499    0.08018   -0.00230   -0.08080   -0.15035   -0.20400   -0.22594
-0.18907    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
22.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0       -0.08210   -0.11309   -0.11150   -0.09325
-0.05172    0.00029    0.05948    0.12490    0.19888    0.27284    0.35051    0.42839
 0.50575    0.58186    0.65559    0.72611    0.79366    0.85758    0.91575    0.96929
 1.01819    1.06246    1.10208    1.13706    1.16739    1.19307    1.21410    1.23048
 1.24221    1.24927    1.25167    1.24941    1.24248    1.23089    1.21462    1.19368
 1.16806    1.13777    1.10279    1.06313    1.01878    0.96975    0.91602    0.85760
 0.79361    0.72623    0.65541    0.58214    0.50613    0.42890    0.35116    0.27368
 0.19782    0.12365    0.05799   -0.00140   -0.05362   -0.09128   -0.11356   -0.11123
-0.08349    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
37.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.00633    0.00492    0.00620    0.00896
 0.02571    0.04994    0.07978    0.11559    0.16766    0.21854    0.28122    0.34803
 0.41828    0.49114    0.56893    0.64441    0.72083    0.79401    0.86161    0.92412
 0.98150    1.03370    1.08069    1.12243    1.15889    1.19001    1.21577    1.23612
 1.25103    1.26045    1.26435    1.26269    1.25543    1.24252    1.22394    1.19963
 1.16957    1.13371    1.09202    1.04445    0.99097    0.93153    0.86610    0.79464
 0.72004    0.64533    0.56784    0.49240    0.41969    0.34960    0.28295    0.22047
 0.16559    0.11342    0.07760    0.04782    0.02366    0.01076    0.00466    0.00604
 0.00567    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
52.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
```

```
 0.0        0.0        0.0        0.0        0.03333    0.05434    0.07108    0.08521
 0.10243    0.12194    0.14333    0.16664    0.20163    0.23424    0.27833    0.32723
 0.38086    0.43898    0.50877    0.57724    0.65221    0.72459    0.79195    0.85399
 C.91073    0.96214    1.00821    1.04894    1.08431    1.11432    1.13896    1.15822
 1.17208    1.18054    1.18359    1.18122    1.17341    1.16017    1.14147    1.11732
 1.08770    1.05260    1.01201    0.96592    0.91433    0.85721    0.79458    0.72640
 0.65018    0.57933    0.50655    0.44125    0.38311    0.32944    0.28047    0.23634
 0.19967    0.16483    0.14179    0.12068    0.10140    0.08595    0.07059    0.05459
 0.03325    C.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
67.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.03181    0.05717    0.08101    0.10520
 0.13010    0.15680    0.18588    0.21685    0.25177    0.28727    0.32823    0.37235
 0.41948    0.46941    0.52874    0.58699    0.65222    0.71481    0.77276    0.82613
 0.87493    0.91914    0.95877    0.99379    1.02420    1.05000    1.07118    1.08772
 1.09964    1.10691    1.10953    1.10749    1.10079    1.08941    1.07335    1.05261
 1.02718    0.99704    0.96220    0.92264    0.87835    0.82934    0.77559    0.71709
 0.64989    0.58918    0.52663    0.47135    0.42120    0.37384    0.32951    0.28838
 0.25089    0.21614    0.18539    0.15649    0.12992    0.10528    0.08101    0.05712
 0.03186    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
82.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.02752    0.05118    0.07517    0.10129
 0.12894    0.15940    0.19399    0.23247    0.27224    0.31651    0.36336    0.41329
 0.46575    0.52001    0.57776    0.63557    0.69598    0.75454    0.80925    0.85971
 0.90592    0.94785    0.98548    1.01881    1.04781    1.07247    1.09277    1.10870
 1.12024    1.12737    1.13008    1.12835    1.12217    1.11152    1.09638    1.07674
 1.05258    1.02388    C.99063    0.95282    0.91042    0.86342    0.81181    0.75556
 0.69500    0.63643    0.57700    0.52067    0.46628    0.41372    0.36369    0.31676
 0.27207    0.23237    0.19395    0.15939    0.12895    0.10126    0.07521    0.05114
 0.02755    C.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 C.0        0.0        0.0        0.0        0.0


                CASE #4
         THE ASYMMETRIC TEST CASE OF FIGURE 8
       RUN UNDER MODE 3
*****************************************************************************
       NECESSARY DATA CARDS
*****************************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
```

```
QUARE CN (Y)
EVERETT INTRPL(LINEAR) OF FIGURE #8
    CASE #4
 1.176     .6941
         3        101         6          1   2.00000   0.50000
************************************************************************
    CONTINUE ENTERING FRINGE SHIFT INFORMATICN
            OBTAINED FROM CASE #1
************************************************************************
    THE MODIFIED OUTPUT FRINGE SHIFT INFORMATICN
                 FOR THIS CASE IS:
************************************************************************
  7.50000
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0       -0.18822   -0.22693   -0.20304   -0.15116
  -0.08012   -0.00176    0.08060    0.16530    0.24902    0.33243    0.41315    0.49143
   0.56688    0.63918    0.70646    0.77017    0.83009    0.88627    0.88627    0.88627
   0.88627    0.88626    0.88626    0.88626    0.88626    0.88626    0.88626    0.88625
   0.88625    0.88625    0.88625    0.88625    0.88625    0.88625    0.88624    0.88624
   0.88624    0.88624    0.88624    0.88624    0.88623    0.88623    0.88623    0.88623
   0.83013    0.77014    0.70649    0.63918    0.56691    0.49149    0.41325    0.33258
   0.24880    0.16499    0.08018   -0.00230   -0.08080   -0.15035   -0.20400   -0.22594
  -0.18907    0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0
 22.50000
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0       -0.08210   -0.11309   -0.11150   -0.09325
  -0.05172    0.00029    0.05948    0.12490    0.19888    0.27284    0.35051    0.42839
   0.50575    0.58186    0.65559    0.72611    0.79366    0.85758    0.85758    0.85758
   0.85758    0.85758    0.85758    0.85758    0.85759    0.85759    0.85759    0.85759
   0.85759    0.85759    0.85759    0.85759    0.85759    0.85759    0.85759    0.85759
   0.85759    0.85760    0.85760    0.85760    0.85760    0.85760    0.85760    0.85760
   0.79361    0.72623    0.65541    0.58214    0.50613    0.42890    0.35116    0.27368
   0.19782    0.12365    0.05799   -0.00140   -0.05362   -0.09128   -0.11356   -0.11123
  -0.08349    0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0
 37.50000
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.00633    0.00492    0.00620    0.00896
   0.02571    0.04994    0.07978    0.11559    0.16766    0.21854    0.28122    0.34803
   0.41828    0.49114    0.56893    0.64441    0.72083    0.79401    0.79403    0.79406
   0.79408    0.79411    0.79413    0.79416    0.79418    0.79420    0.79423    0.79425
   0.79428    0.79430    0.79432    0.79435    0.79437    0.79440    0.79442    0.79445
```

```
  0.79447    0.79449    0.79452    0.79454    0.79457    0.79459    0.79462    0.79464
  0.72004    0.64533    0.56784    0.49240    0.41969    0.34960    0.28295    0.22047
  0.16559    0.11342    0.07760    0.04782    0.02366    0.01076    0.00466    0.00604
  0.00567    0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0
52.50000
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.03333    0.05434    0.07108    0.08521
  0.10243    0.12194    0.14333    0.16664    0.20163    0.23424    0.27833    0.32723
  0.38086    0.43898    0.50877    0.57724    0.65221    0.72459    0.72466    0.72473
  0.72480    0.72487    0.72494    0.72501    0.72508    0.72515    0.72522    0.72529
  0.72536    0.72543    0.72549    0.72556    0.72563    0.72570    0.72577    0.72584
  0.72591    0.72598    0.72605    0.72612    0.72619    0.72626    0.72633    0.72640
  0.65018    0.57933    0.50655    0.44125    0.38311    0.32944    0.28047    0.23634
  0.19967    0.16483    0.14179    0.12068    0.10140    0.08595    0.07059    0.05459
  0.03325    0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0
67.50000
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.03181    0.05717    0.08101    0.10520
  0.13010    0.15680    0.18588    0.21685    0.25177    0.28727    0.32823    0.37235
  0.41948    0.46941    0.52874    0.58699    0.65222    0.71481    0.71490    0.71499
  0.71507    0.71516    0.71525    0.71534    0.71542    0.71551    0.71560    0.71569
  0.71577    0.71586    0.71595    0.71604    0.71613    0.71621    0.71630    0.71639
  0.71648    0.71656    0.71665    0.71674    0.71683    0.71691    0.71700    0.71709
  0.64989    0.58918    0.52663    0.47135    0.42120    0.37384    0.32951    0.28838
  0.25089    0.21614    0.18539    0.15649    0.12992    0.10528    0.08101    0.05712
  0.03186    0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0
82.50000
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.02752    0.05118    0.07517    0.10129
  0.12894    0.15940    0.19399    0.23247    0.27224    0.31651    0.36336    0.41329
  0.46575    0.52001    0.57776    0.63557    0.69598    0.75454    0.75458    0.75462
  0.75466    0.75470    0.75474    0.75478    0.75481    0.75485    0.75489    0.75493
  0.75497    0.75501    0.75505    0.75509    0.75513    0.75517    0.75521    0.75525
  0.75529    0.75532    0.75536    0.75540    0.75544    0.75548    0.75552    0.75556
  0.69500    0.63643    0.57700    0.52067    0.46628    0.41372    0.36369    0.31676
  0.27207    0.23237    0.19395    0.15939    0.12895    0.10126    0.07521    0.05114
  0.02755    0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0
```

```
                             CASE #5
     THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
     CENTER BY 0.25 IN THE X AND Y DIRECTIONS
     RUN UNDER MODE 1
     YJ=YJ-0.25
     Y2=YJ*YJ
     XI=XI-0.25
     X2=XI*XI
     VAL=(1.-Y2)*EXP(-2.*X2)
     R2=Y2+X2
     IF(R2.GT.1.5) VAL = 0.
     RETURN
     END
**********************************************************************
     NECESSARY DATA CARDS
**********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE ON (Y)
     MODE 1 (DISPLACED) STANDARD CASE
CASE #5
 1.176     .6941
        1       101        12         0      2.0        .5
   07.5      22.5      37.5      52.5      67.5      82.5      97.5     112.5
  127.5     142.5     157.5     172.5
**********************************************************************
**********************************************************************


                             CASE #7
     THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
     CENTER BY 0.25 IN THE X AND Y DIRECTIONS
     RUN UNDER MODE 3
**********************************************************************
     NECESSARY DATA CARDS
**********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE ON (Y)
EVERETT INTRPL OF FIGURE #8 (DISPLACED)
     CASE #7
 1.176     .6941
        3       101        12         0      2.0        .5
*********************************************************************
     CONTINUE ENTERING FRINGE SHIFT INFORMATION
              OBTAINED FROM CASE #5
*********************************************************************
     THE MODIFIED OUTPUT FRINGE SHIFT INFORMATION
```

```
                   FOR THIS CASE IS:
**********************************************************************
  7.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0      -0.13023  -0.22792  -0.21639  -0.17190  -0.10786  -0.03227   0.04915
  0.13230   0.21709   0.30073   0.38260   0.46169   0.53802   0.60989   0.67788
  0.74199   0.80220   0.85850   0.91088   0.95932   1.00383   1.04438   1.08097
  1.11358   1.14221   1.16685   1.18747   1.20408   1.21666   1.22519   1.22968
  1.23010   1.22646   1.21872   1.20690   1.19096   1.17091   1.14674   1.11842
  1.08448   1.04690   1.00441   0.95781   0.90730   0.85223   0.79338   0.73177
  0.66494   0.59461   0.52006   0.44302   0.36309   0.28102   0.19758   0.11256
  0.02868  -0.05159  -0.12560  -0.18595  -0.22272  -0.21363   0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
 22.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0      -0.05321
 -0.10985  -0.11971  -0.10013  -0.06836  -0.02300   0.03531   0.09879   0.17160
  0.24465   0.32121   0.39935   0.47700   0.55351   0.62740   0.69711   0.76289
  0.82468   0.88245   0.93616   0.98574   1.03117   1.07239   1.10937   1.14204
  1.17038   1.19433   1.21384   1.22888   1.23940   1.24536   1.24670   1.24338
  1.23536   1.22259   1.20503   1.18263   1.15535   1.12314   1.08596   1.04375
  0.99434   0.94047   0.88204   0.81930   0.75250   0.68268   0.61059   0.53539
  0.45812   0.38087   0.30294   0.22608   0.15183   0.08195   0.01962  -0.03300
 -0.07863  -0.10565  -0.11872  -0.09991  -0.00586   0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
 37.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.00608   0.00508   0.00287
  0.01097   0.02244   0.04074   0.07147   0.10856   0.15807   0.20954   0.27345
  0.33753   0.40841   0.48087   0.55761   0.63255   0.70929   0.78210   0.85016
  0.91341   0.97177   1.02517   1.07354   1.11682   1.15493   1.18780   1.21536
  1.23753   1.25426   1.26547   1.27109   1.27105   1.26527   1.25369   1.23624
  1.21285   1.18344   1.14795   1.10630   1.05843   1.00426   0.94373   0.87676
  0.80498   0.73176   0.65544   0.58059   0.50328   0.43136   0.35962   0.29398
  0.22605   0.17588   0.12500   0.08315   0.05138   0.02831   0.01399   0.00700
  0.00441   0.00614   0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
 52.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.03739   0.05728   0.07287   0.08734   0.10579
```

```
 0.12320      0.14594      0.17072      0.20480      0.24027      0.28602      0.33741      0.39290
 0.45313      0.51624      0.59054      0.65924      0.73348      0.80990      0.87996      0.94264
 0.99810      1.04649      1.08797      1.12270      1.15082      1.17251      1.18790      1.19716
 1.20045      1.19791      1.18971      1.17600      1.15693      1.13267      1.10337      1.06918
 1.03027      0.98677      0.93886      0.88669      0.83041      0.77018      0.70615      0.63848
 0.56495      0.49683      0.43683      0.37237      0.32079      0.26958      0.23162      0.19364
 0.16064      0.13951      0.11777      0.09926      0.08287      0.06915      0.05184      0.02845
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0
67.50000
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.00196      0.04217      0.06692      0.08968      0.11442      0.13980      0.16770      0.19773
 0.22941      0.26507      0.30178      0.34431      0.39062      0.43890      0.49051      0.55138
 0.61209      0.67023      0.73846      0.80225      0.87492      0.94171      0.99402      1.03824
 1.07471      1.10375      1.12566      1.14078      1.14941      1.15189      1.14852      1.13964
 1.12555      1.10658      1.08305      1.05527      1.02358      0.98827      0.94969      0.90814
 0.86394      0.81742      0.76889      0.71868      0.66710      0.61447      0.56111      0.50734
 0.44903      0.40071      0.35524      0.31279      0.27299      0.23597      0.20452      0.17372
 0.14630      0.12003      0.09564      0.07210      0.04863      0.01902      0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0
82.50000
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.03668
 0.06042      0.08471      0.11167      0.13996      0.17294      0.20819      0.24621      0.28930
 0.33364      0.38227      0.43338      0.48724      0.54205      0.59942      0.65905      0.71769
 0.77761      0.83455      0.89165      0.94351      0.99909      1.04716      1.07712      1.10078
 1.11839      1.13021      1.13650      1.13751      1.13351      1.12474      1.11147      1.09395
 1.07244      1.04720      1.01848      0.98655      0.95165      0.91405      0.87400      0.83176
 0.78758      0.74174      0.69447      0.64604      0.59671      0.54673      0.49636      0.44585
 0.39427      0.34554      0.29899      0.25639      0.21654      0.18042      0.14745      0.11807
 0.09035      0.06615      0.04324      0.01628      0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0
97.50000
 0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
 0.0          0.0          0.0          0.0          0.0          0.02820      0.05137      0.07587
 0.10064      0.12860      0.16003      0.19471      0.23229      0.27323      0.31668      0.36459
 0.41434      0.46603      0.52151      0.57739      0.63538      0.69608      0.75289      0.81303
 0.86940      0.92737      0.98068      1.03256      1.07850      1.12107      1.14828      1.16791
 1.18037      1.18602      1.18525      1.17845      1.16599      1.14825      1.12563      1.09849
 1.06724      1.03223      0.99387      0.95253      0.90859      0.86244      0.81445      0.76502
 0.71452      0.66334      0.61185      0.56045      0.50950      0.45941      0.41053      0.36327
 0.31639      0.27181      0.23113      0.19408      0.15964      0.12821      0.10094      0.07486
```

```
  0.05150  0.02738    0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0
112.50000
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.03671    0.06136    0.08493    0.10895
  0.13461  0.16143    0.19016    0.22210    0.25748    0.29488    0.33501    0.38241
  0.4284C  0.47873    0.53581    0.59902    0.65801    0.72601    0.79164    0.86066
  0.92928  0.98783    1.05143    1.11083    1.16453    1.21169    1.19805    1.18113
  1.16111  1.13820    1.11256    1.08441    1.05392    1.02128    0.98669    C.95032
  0.91238  0.87305    0.83252    0.79098    0.74862    0.70563    0.66219    0.61850
  0.57475  0.53112    0.48780    0.44499    0.40287    0.36163    0.32146    0.28255
  0.24418  0.21101    0.18033    0.15259    0.12547    0.10095    0.07740    0.05373
  0.02686  0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0
127.50000
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.02658    0.05031    0.06751    0.08242    0.09867
  0.11565  0.13537    0.15930    0.19096    0.2274C    0.26803    0.31298    0.37054
  0.42826  0.49427    0.55980    0.63216    0.70885    0.77984    0.85719    0.92943
  1.00122  1.06956    1.13235    1.18920    1.23928    1.28186    1.28639    1.28296
  1.272C8  1.25431    1.23018    1.20023    1.16498    1.12498    1.08076    1.03287
  0.98183  0.92818    0.87247    0.81522    0.75697    0.69826    0.63962    0.58159
  0.52472  0.46952    0.41655    0.36633    0.31941    0.27632    0.23759    0.20376
  C.17340  0.14988    0.12273    0.10758    0.08992    0.07460    0.05834    0.03948
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0
142.50000
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.00545    0.00408    0.00485    0.00895    0.01976
  0.04371  0.07220    0.10576    0.15493    0.20355    0.26392    0.33416    0.40218
  0.47495  0.55145    0.62638    0.70273    0.77597    0.84909    0.91799    0.98441
  1.04541  1.10166    1.15254    1.19762    1.23663    1.26931    1.26799    1.26087
  1.24827  1.23051    1.20791    1.18079    1.14946    1.11423    1.07544    1.03339
  0.98840  0.94079    0.89087    0.83897    0.7854C    0.73048    0.67453    0.61787
  0.56080  0.50365    0.44674    0.39038    0.33490    0.28060    0.22781    0.17684
  0.12590  0.08429    0.05365    C.02801    0.01099    0.00407    0.00541    0.00484
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0      0.0        0.0        0.0        0.0
157.500C0
  0.0      0.0        0.0        0.0        0.0        0.0        0.0        0.0
```

```
   0.0        0.0        0.0        0.0       -0.08987   -0.11626   -0.11245   -0.08521
  -0.04636    0.00831    0.06964    0.13709    0.21008    0.28663    0.36423    0.44164
   0.51894    0.59428    0.66775    0.73774    0.80473    0.86812    0.92812    0.98271
   1.03398    1.08017    1.12132    1.15834    1.19002    1.21685    1.23329    1.24406
   1.24933    1.24927    1.24407    1.23390    1.21893    1.19935    1.17533    1.14704
   1.11467    1.07839    1.03837    0.99480    0.94785    0.89770    0.84452    0.78849
   0.72979    0.66859    0.60507    0.53941    0.47178    0.40236    0.33133    0.25886
   0.18562    0.11218    0.04893   -0.01192   -0.06005   -0.09448   -0.11646   -0.11135
  -0.07193    0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0
 172.50000
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0       -0.19214   -0.22718   -0.20347
  -0.14890   -0.07939   -0.00099    0.08203    0.16579    0.25050    0.33353    0.41442
   0.49311    0.56750    0.63965    0.70689    0.77149    0.83088    0.88747    0.93913
   0.98826    1.03143    1.07111    1.10619    1.13823    1.16517    1.18503    1.20083
   1.21259    1.22032    1.22405    1.22380    1.21958    1.21141    1.19932    1.18332
   1.16343    1.13968    1.11208    1.08065    1.04542    1.00639    0.96360    0.91705
   0.86678    0.81279    0.75511    0.69377    0.62877    0.56013    0.48789    0.41205
   0.33161    0.24794    0.16397    0.07949   -0.00292   -0.08149   -0.15018   -0.20405
  -0.22861   -0.18649    0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0        0.0        0.0

                                  CASE #8
    THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
    CENTER BY 0.25 IN THE X AND Y DIRECTIONS
    RUN UNDER MODE 3
************************************************************
    NECESSARY DATA CARDS
************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE ON (Y)
    CASE #8
 1.176    .6941
      3       101        12         0      2.0        .5
************************************************************
    CONTINUE ENTERING FRINGE SHIFT INFORMATION
            OBTAINED FROM CASE #5
************************************************************
    THE MODIFIED OUTPUT FRINGE SHIFT INFORMATICN
                 FOR THIS CASE IS:
************************************************************
  7.50000
```

```
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0       -0.13023   -0.22792   -0.21639   -0.17190   -0.10786   -0.03227    0.04915
 0.13230    0.21709    0.30073    0.38260    0.46169    0.53802    0.56034    0.58267
 0.60499    0.62731    0.64964    0.67196    0.69428    0.71660    0.73893    0.76125
 0.78357    0.80590    0.82822    0.85054    0.87287    0.89519    0.91751    0.93983
 0.96216    0.98448    1.00680    1.02913    1.05145    1.07377    1.09610    1.11842
 1.08448    1.04690    1.00441    0.95781    0.90730    0.85223    0.79338    0.73177
 0.66494    0.59461    0.52006    0.44302    0.36309    0.28102    0.19758    0.11256
 0.02868   -0.05159   -0.12560   -0.18595   -0.22272   -0.21363    0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
22.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0       -0.05321
-0.10985   -0.11971   -0.10013   -0.06836   -0.02300    0.03531    0.09879    0.17160
 0.24465    0.32121    0.39935    0.47700    0.55351    0.62740    0.64341    0.65943
 0.67544    0.69145    0.70747    0.72348    0.73949    0.75551    0.77152    0.78753
 0.80355    0.81956    0.83557    0.85159    0.86760    0.88362    0.89963    0.91564
 0.93166    0.94767    0.96368    0.97970    0.99571    1.01172    1.02774    1.04375
 0.99434    0.94047    0.88204    0.81930    0.75250    0.68268    0.61059    0.53539
 0.45812    0.38087    0.30294    0.22608    0.15183    0.08195    0.01962   -0.03300
-0.07863   -0.10565   -0.11872   -0.09991   -0.00586    0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
37.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.00608    0.00508    0.00287
 0.01097    0.02244    0.04074    0.07147    0.10856    0.15807    0.20954    0.27345
 0.33753    0.40841    0.48087    0.55761    0.63255    0.70929    0.71573    0.72217
 0.72861    0.73505    0.74150    0.74794    0.75438    0.76082    0.76726    0.77370
 0.78014    0.78658    0.79302    0.79947    0.80591    0.81235    0.81879    0.82523
 0.83167    0.83811    0.84455    0.85100    0.85744    0.86388    0.87032    0.87676
 0.80498    0.73176    0.65544    0.58059    0.50328    0.43136    0.35962    0.29398
 0.22605    0.17588    0.12500    0.08315    0.05138    0.02831    0.01399    0.00700
 0.00441    0.00614    0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
52.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.03739    0.05728    0.07287    0.08734    0.10579
 0.12320    0.14594    0.17072    0.20480    0.24027    0.28602    0.33741    0.39290
 0.45313    0.51624    0.59054    0.65924    0.73348    0.80990    0.80331    0.79671
 0.79012    0.78353    0.77693    0.77034    0.76375    0.75716    0.75056    0.74397
```

```
0.73738   0.73078   0.72419   0.71760   0.71100   0.70441   0.69782   0.69122
0.68463   0.67804   0.67145   0.66485   0.65826   0.65167   0.64507   0.63848
0.56495   0.49683   0.43683   0.37237   0.32079   0.26958   0.23162   0.19364
0.16064   0.13951   0.11777   0.09926   0.08287   0.06915   0.05184   0.02845
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0
67.50000
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.00196   0.04217   0.06692   0.08968   0.11442   0.13980   0.16770   0.19773
0.22941   0.26507   0.30178   0.34431   0.39062   0.43890   0.49051   0.55138
0.61209   0.67023   0.73846   0.80225   0.87492   0.94171   0.92500   0.90830
0.89159   0.87488   0.85818   0.84147   0.82476   0.80806   0.79135   0.77464
0.75794   0.74123   0.72453   0.70782   0.69111   0.67441   0.65770   0.64099
0.62429   0.60758   0.59087   0.57417   0.55746   0.54075   0.52405   0.50734
0.44903   0.40071   0.35524   0.31279   0.27299   0.23597   0.20452   0.17372
0.14630   0.12003   0.09564   0.07210   0.04863   0.01902   0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0
82.50000
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.03668
0.06042   0.08471   0.11167   0.13996   0.17294   0.20819   0.24621   0.28930
0.33364   0.38227   0.43338   0.48724   0.54205   0.59942   0.65905   0.71769
0.77761   0.83455   0.89165   0.94351   0.99909   1.04716   1.02403   1.00090
0.97778   0.95465   0.93152   0.90840   0.88527   0.86214   0.83901   0.81589
0.79276   0.76963   0.74651   0.72338   0.70025   0.67712   0.65400   0.63087
0.60774   0.58461   0.56149   0.53836   0.51523   0.49210   0.46898   0.44585
0.39427   0.34554   0.29899   0.25639   0.21654   0.18042   0.14745   0.11807
0.09035   0.06615   0.04324   0.01628   0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0
97.50000
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.02820   0.05137   0.07587
0.10064   0.12860   0.16003   0.19471   0.23229   0.27323   0.31668   0.36459
0.41434   0.46603   0.52151   0.57739   0.63538   0.69608   0.75289   0.81303
0.86940   0.92737   0.98068   1.03256   1.07850   1.12107   1.09192   1.06278
1.03363   1.00449   0.97534   0.94619   0.91705   0.88790   0.85876   0.82961
0.80046   0.77132   0.74217   0.71302   0.68388   0.65473   0.62559   0.59644
0.56729   0.53815   0.50900   0.47986   0.45071   0.42156   0.39242   0.36327
0.31639   0.27181   0.23113   0.19408   0.15964   0.12821   0.10094   0.07486
0.05150   0.02738   0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
```

```
  0.0       0.0       0.0       0.0       0.0
112.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.03671   0.06136   0.08493   0.10895
  0.13461   0.16143   0.19016   0.22210   0.25748   0.29488   0.33501   0.38241
  0.42840   0.47873   0.53581   0.59902   0.65801   0.72601   0.79164   0.86066
  0.92928   0.98783   1.05143   1.11083   1.16453   1.21169   1.17595   1.14022
  1.10448   1.06875   1.03301   0.99727   0.96154   0.92580   0.89007   0.85433
  0.81859   0.78286   0.74712   0.71138   0.67565   0.63991   0.60418   0.56844
  0.53270   0.49697   0.46123   0.42549   0.38976   0.35402   0.31829   0.28255
  0.24418   0.21101   0.18033   0.15259   0.12547   0.10095   0.07740   0.05373
  0.02686   0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
127.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.02658   0.05031   0.06751   0.08242   0.09867
  0.11565   0.13537   0.15930   0.19096   0.22740   0.26803   0.31298   0.37054
  0.42826   0.49427   0.55980   0.63216   0.70885   0.77984   0.85719   0.92943
  1.00122   1.06956   1.13235   1.18920   1.23928   1.28186   1.24039   1.19893
  1.15746   1.11600   1.07453   1.03307   0.99160   0.95014   0.90867   0.86721
  0.82574   0.78428   0.74281   0.70135   0.65988   0.61841   0.57695   0.53548
  0.49402   0.45255   0.41109   0.36962   0.32816   0.28669   0.24523   0.20376
  0.17340   0.14988   0.12273   0.10758   0.08992   0.07460   0.05834   0.03948
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
142.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.00545   0.00408   0.00485   0.00895   0.01976
  0.04371   0.07220   0.10576   0.15493   0.20355   0.26392   0.33416   0.40218
  0.47495   0.55145   0.62638   0.70273   0.77597   0.84909   0.91799   0.98441
  1.04541   1.10166   1.15254   1.19762   1.23663   1.26931   1.22729   1.18527
  1.14326   1.10124   1.05922   1.01720   0.97518   0.93317   0.89115   0.84913
  0.80711   0.76509   0.72308   0.68106   0.63904   0.59702   0.55500   0.51299
  0.47097   0.42895   0.38693   0.34491   0.30290   0.26088   0.21886   0.17684
  0.12590   0.08429   0.05365   0.02801   0.01099   0.00407   0.00541   0.00484
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
157.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0      -0.08987  -0.11626  -0.11245  -0.08521
 -0.04636   0.00831   0.06964   0.13709   0.21008   0.28663   0.36423   0.44164
  0.51894   0.59428   0.66775   0.73774   0.80473   0.86812   0.92812   0.98271
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   1.03398     1.08017     1.12132     1.15834     1.19002     1.21685     1.18000     1.14316
   1.10631     1.06947     1.03262     0.99578     0.95893     0.92208     0.88524     0.84839
   0.81155     0.77470     0.73786     0.70101     0.66416     0.62732     0.59047     0.55363
   0.51678     0.47993     0.44309     0.40624     0.36940     0.33255     0.29571     0.25886
   0.18562     0.11218     0.04893    -0.01192    -0.06005    -0.09448    -0.11646    -0.11135
  -0.07193     0.0         0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0
 172.50000
   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0        -0.19214    -0.22718    -0.20347
  -0.14890    -0.07939    -0.00099     0.08203     0.16579     0.25050     0.33353     0.41442
   0.49311     0.56750     0.63965     0.70689     0.77149     0.83088     0.88747     0.93913
   0.98826     1.03143     1.07111     1.10619     1.13823     1.16517     1.13620     1.10724
   1.07827     1.04930     1.02034     0.99137     0.96241     0.93344     0.90447     0.87551
   0.84654     0.81758     0.78861     0.75964     0.73068     0.70171     0.67275     0.64378
   0.61481     0.58585     0.55688     0.52791     0.49895     0.46998     0.44102     0.41205
   0.33161     0.24794     0.16397     0.07949    -0.00292    -0.08149    -0.15018    -0.20405
  -0.22861    -0.18649     0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
   0.0         0.0         0.0         0.0         0.0
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*************************************************************************
*                                                                       *
*                        ADDITIONAL SUBROUTINES                         *
*                                                                       *
*************************************************************************


      SUBROUTINE CTRMAP(A,NMAP,N,M)                                     CTR00010
                                                                        CTR00020
  THIS SUBROUTINE WILL GIVE A MAP OF THE NUMBERS CONTAINED ARRAY A      CTR00030
  FOUR PARAMETERS MUST BE FURNISHED TO THE SUBROUTINE                   CTR00040
                                                                        CTR00050
             A IS THE NAME OF THE ARRAY TO BE MAPPED                    CTR00060
             N IS THE NUMBER OF LINES IN THE MAP                        CTR00070
             M IS THE WIDTH OF THE LINE, MAXIMUM IS 115                 CTR00080
             NMAP IS A FIXED POINT IDENTIFICATION NUMBER FOR THE MAP    CTR00090
                                                                        CTR00100
             TWENTY SYMBOLS ARE USED IN THE PRODUCTION OF THE MAP       CTR00110
             THEY ARE: A,B,C,D,E,F,G,H,I,J,,,O,,,Q,R,S,T,U,V,W,X,Y,Z.   CTR00120
                                                                        CTR00130
             AT THE TOP OF THE MAP THE VALUES OF THE SYMBOLS ARE LISTED CTR00140
             THE USER SHOULD REALIZE THAT THIS IS AN OUTPUT SUBROUTINE  CTR00150
             THAT WILL PRODUCE A DIGITAL PLOT EVERY TIME IT IS CALLED   CTR00160
                                                                        CTR00170
             THE USER IS ALSO WARNED THAT THIS SUBROUTINE IS NOT GOING  CTR00180
             TO INTERPOLATE FOR SUPPLEMENTARY POINTS, THE MAP IS        CTR00190
             PRODUCED WITH THE ARRAY A EXCLUSIVELY                      CTR00200
                                                                        CTR00210
  CODED BY:    PROFESSOR GILLES CANTIN, (59CI) IN 1964 FOR THE CDC/1604 CTR00220
  REVISED AND ADAPTED FOR THE IBM/67  SEVERAL TIMES , BY THE AUTHOR     CTR00230
  THIS VERSION IS DATED OCTOBER 1,1969.                                 CTR00240
                                                                        CTR00250
      DIMENSION LINE(115),ISYMB(42),BV(21),A(N,M)                       CTR00260
      DATA ISYMB/1H ,1HO,1H ,1HA,1H ,1HB,1H ,1HC,1H ,1HD,1H ,1HE        CTR00270
     1,1H ,1HF,1H ,1HG,1H ,1HH,1H ,1HI,1H ,1HJ,1H ,1HQ,1H ,1HR,1H ,1HS, CTR00280
     21H ,1HT,1H ,1HU,1H ,1HV,1H ,1HW,1H ,1HX,1H ,1HY,1H ,1HZ/          CTR00290
      DATA IBLK/1H /                                                    CTR00300
      AMIN=1.E+70                                                       CTR00310
      DO 6 I=1,N                                                        CTR00320
      DO 5 J=1,M                                                        CTR00330
    5 AMIN=AMIN1(AMIN,A(I,J))                                           CTR00340
    6 CONTINUE                                                          CTR00350
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      DO 8 I=1,N                                                        CTR00360
      DO 7 J=1,M                                                        CTR00370
    7 A(I,J)=A(I,J)-AMIN                                                CTR00380
    8 CONTINUE                                                          CTR00390
      AMAX=-1.E+70                                                      CTR00400
      DO 11 I=1,N                                                       CTR00410
      DO 10 J=1,M                                                       CTR00420
   10 AMAX=AMAX1(AMAX,A(I,J))                                           CTR00430
   11 CONTINUE                                                          CTR00440
      RGE=AMAX                                                          CTR00450
      IF(ABS(RGE)-1.0E-10) 12,12,13                                     CTR00460
   12 WRITE(6,1000)                                                     CTR00470
      WRITE(6,1400) RGE,AMAX,AMIN                                       CTR00480
 1400 FORMAT(//,5X,13H THE RANGE IS,E15.6,/,5X,13H   MAXIMUM IS,E15.6,/,CTR00490
     15X,13H   MINIMUM IS,E15.6)                                        CTR00500
      RETURN                                                            CTR00510
   13 CONTINUE                                                          CTR00520
      SCF=40./AMAX                                                      CTR00530
      DO 21 I=1,N                                                       CTR00540
      DO 20 J=1,M                                                       CTR00550
   20 A(I,J)=SCF*A(I,J)                                                 CTR00560
   21 CONTINUE                                                          CTR00570
      DO 30 I=1,21                                                      CTR00580
      AI=FLOAT(I-1)                                                     CTR00590
   30 BV(I)=(2.*AI/SCF)+AMIN                                            CTR00600
      WRITE(6,1000)                                                     CTR00610
      WRITE(6,1050)                                                     CTR00620
      WRITE(6,1300) BV(1),BV(1),BV(21)                                  CTR00630
      WRITE(6,1100) BV(2),BV(3),BV(4),BV(5),BV(6)                       CTR00640
      WRITE(6,1200) BV(7),BV(8),BV(9),BV(10),BV(11)                     CTR00650
      WRITE(6,1210) BV(12),BV(13),BV(14),BV(15),BV(16)                  CTR00660
      WRITE(6,1220) BV(17),BV(18),BV(19),BV(20),BV(21)                  CTR00670
      WRITE(6,1050)                                                     CTR00680
      M1=M+1                                                            CTR00690
      DO 50 K=1,N                                                       CTR00700
      DO 40 J=1,M                                                       CTR00710
      AJ=A(K,J)+2.50001                                                 CTR00720
      JJ=INT(AJ)                                                        CTR00730
   40 LINE(J)=ISYMB(JJ)                                                 CTR00740
      IF(M1-115) 41,41,46                                               CTR00750
   41 CONTINUE                                                          CTR00760
      DO 45 I=M1,115                                                    CTR00770
   45 LINE(I)=IBLK                                                      CTR00780
   46 CONTINUE                                                          CTR00790
      WRITE(6,2000) LINE                                                CTR00800
   50 CONTINUE                                                          CTR00810
      DO 61 I=1,N                                                       CTR00820
      DO 60 J=1,M                                                       CTR00830
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   60 A(I,J)=A(I,J)/SCF +AMIN                                                CTR00840
   61 CONTINUE                                                               CTR00850
      WRITE(6,2500) NMAP                                                     CTR00860
 2500 FORMAT(//,5X,4H MAP,I3)                                                CTR00870
 1000 FORMAT(1H1)                                                            CTR00880
 1050 FORMAT(//)                                                             CTR00890
 1100 FORMAT(5X,3H A=,F8.3,3X,3H B=,F8.3,3X,3H C=,F8.3,3X,3H D=,F8.3,         CTR00900
     13X,3H E=,F8.3)                                                         CTR00910
 1200 FORMAT(5X,3H F=,F8.3,3X,3H G=,F8.3,3X,3H H=,F8.3,3X,3H I=,F8.3,         CTR00920
     13X,3H J=,F8.3)                                                         CTR00930
 1210 FORMAT(5X,3H Q=,F8.3,3X,3H R=,F8.3,3X,3H S=,F8.3,3X,3H T=,F8.3,         CTR00940
     13X,3H U=,F8.3)                                                         CTR00950
 1220 FORMAT(5X,3H V=,F8.3,3X,3H W=,F8.3,3X,3H X=,F8.3,3X,3H Y=,F8.3,         CTR00960
     13X,3H Z=,F8.3)                                                         CTR00970
 1300 FORMAT(5X,3H O=,F10.6,5X,7H RANGE(,E15.6,5X,E15.6,2H ))                 CTR00980
 2000 FORMAT(2X,115A1)                                                       CTR00990
      END                                                                    CTR01000


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.......................................................................CNTR0010
                                                                       CNTR0020

                   SUBROUTINE CONTUR                                   CNTR0030
                                                                       CNTR0040
   1. IDENTIFICATION                                                   CNTR0050
                                                                       CNTR0060
      A. NAME: GENERATE CONTOUR GRAPH (CONTUR) - J5                    CNTR0070
                                                                       CNTR0080
      B. PROGRAMMER: BERNADETTE R.PEAVEY, 7 JULY 1969                   CNTR0090
                                                                       CNTR0100
   2. PURPOSE                                                          CNTR0110
                                                                       CNTR0120
         CONTUR GENERATES A CONTOUR GRAPH ON WHICH ONE OR MORE         CNTR0130
      (USUALLY MORE) CONTOUR LEVELS ARE DRAWN; THAT IS, GIVEN A MATRIX CNTR0140
      OF NUMERICAL VALUES OF Z=F(X,Y), CONTUR FINDS THE LOCI OF        CNTR0150
      SPECIFIED DISCRETE VALUES OF Z AND PLOTS THESE LOCI (CONTOUR     CNTR0160
      LINES) USING THE OFFLINE PLOTTER.                                CNTR0170
                                                                       CNTR0180
   3. USAGE                                                            CNTR0190
                                                                       CNTR0200
      A. DEFINITIONS                                                   CNTR0210
                                                                       CNTR0220
            IN WHAT FOLLOWS THE WORD GRAPH OR CONTOUR GRAPH WILL BE    CNTR0230
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   TAKEN TO MEAN A COMPLETE CONTOUR PICTURE; THAT IS, ONE PIECE   CNTR0240
   OR FRAME OF GRAPH PAPER ON WHICH ONE OR MORE (USUALLY MORE)    CNTR0250
   CONTOUR LEVELS ARE DRAWN.                                      CNTR0260
                                                                  CNTR0270
       A CONTOUR OR CONTOUR LEVEL WILL MEAN THE PLOT OF THE LOCUSCNTR0280
   ON THE XY PLANE OF ALL Z EQUAL TO A CONSTANT VALUE. NORMALLY,  CNTR0290
   SUCH A CONTOUR WILL CONTAIN MORE THAN ONE CONTOUR SEGMENT.     CNTR0300
                                                                  CNTR0310
       A CONTOUR SEGMENT IS EITHER A CLOSED FIGURE (INTERIOR      CNTR0320
   CONTOUR SEGMENT) OR A CURVE, EACH END OF WHICH TERMINATES AT   CNTR0330
   A MARGIN OF THE CONTOUR GRAPH (EXTERIOR CONTOUR SEGMENT). IT   CNTR0340
   REPRESENTS, IN GENERAL, ONLY A PART OF THE LOCUS ON THE XY     CNTR0350
   PLANE OF ALL Z EQUAL TO SOME VALUE. FOR EXAMPLE, IF Z=F(X,Y)   CNTR0360
   REPRESENTS A RANGE OF THREE MOUNTAINS OF EQUAL ALTITUDE, EACH  CNTR0370
   A CIRCULAR CONE, THEN EVERY CONTOUR SEGMENT WOULD APPEAR AS A  CNTR0380
   CIRCLE. THREE CIRCLES, ONE FOR EACH MOUNTAIN, WOULD MAKE UP    CNTR0390
   ONE CONTOUR OR CONTOUR LEVEL.  THE COMPLETE GRAPH WOULD APPEARCNTR0400
   AS THREE NESTS OF CONCENTRIC CIRCLES.                          CNTR0410
                                                                  CNTR0420
B. CALLING STATEMENT                                              CNTR0430
                                                                  CNTR0440
   CALL CONTUR(AM,M,N,MX,CL,NL,TITLE,IW,IH,LTG)                   CNTR0450
                                                                  CNTR0460
   WHERE:                                                         CNTR0470
                                                                  CNTR0480
   1) AM IS THE REAL*4 DATA MATRIX TO BE CONTOURED AND PLOTTED.   CNTR0490
         IT IS A TWO-DIMENSIONAL ARRAY WHOSE ROW DIMENSION IS     CNTR0500
         PASSED TO CONTUR AS THE PARAMETER MX.                    CNTR0510
                                                                  CNTR0520
   2) M IS AN INTEGER VARIABLE WHICH IS THE NUMBER OF ROWS IN THECNTR0530
        DATA MATRIX TO BE CONTOURED.                              CNTR0540
                                                                  CNTR0550
   3) N IS AN INTEGER VARIABLE WHICH IS THE NUMBER OF COLUMNS IN  CNTR0560
        THE DATA MATRIX TO BE CONTOURED.                          CNTR0570
                                                                  CNTR0580
   4) MX IS AN INTEGER WHICH SPECIFIES THE ROW DIMENSION OF AM.   CNTR0590
         THIS IS THE EXACT NUMBER APPEARING IN THE DIMENSION      CNTR0600
         STATEMENT DEFINING AM.                                   CNTR0610
                                                                  CNTR0620
   5) CL IS A REAL*4 ARRAY CONTAINING THE CONTOUR LEVELS TO BE    CNTR0630
         PLOTTED DIMENSIONED AT LEAST CL(|NL|).                   CNTR0640
                                                                  CNTR0650
   6) NL IS AN INTEGER VARIABLE WHOSE ABSOLUTE VALUE IS THE       CNTR0660
         NUMBER OF CONTOUR LEVELS TO BE FOUND FOR THIS GRAPH. IF  CNTR0670
         NL IS NEGATIVE THEN CONTUR SCANS THE DATA MATRIX FOR THECNTR0680
         LOWEST AND HIGHEST LEVELS TO DETERMINE THE DELTA VALUE   CNTR0690
         FOR PRODUCING |NL| LEVELS OF CONTOURING. IF NL IS        CNTR0700
         POSITIVE, THEN CONTUR ASSUMES THE CL ARRAY CONTAINS      CNTR0710
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        NL ENTRIES OF CONTOUR LEVELS TO BE PLOTTED.                    CNTR0720
                                                                       CNTR0730
    7) TITLE IS A REAL*8 ARRAY DIMENSIONED TITLE(12). CONTUR PICKSCNTR0740
              UP THE MAIN TITLE FROM TITLE(1)-TITLE(6). THE            CNTR0750
              SUBTITLE IS PICKED UP FROM TITLE(7)-TITLE(12). IF THECNTR0760
              USER WISHES HIS TITLES TO BE CENTERED THEN HE MUST       CNTR0770
              STORE HIS CHARACTERS IN TITLE ACCORDINGLY.               CNTR0780
                                                                       CNTR0790
    8) IW IS AN INTEGER VARIABLE SPECIFYING THE WIDTH OF THE           CNTR0800
         CONTOUR GRAPH IN INCHES (1 IW 9).                             CNTR0810
                                                                       CNTR0820
    9) IH IS AN INTEGER VARIABLE SPECIFYING THE HEIGHT OF THE          CNTR0830
         CONTOUR GRAPH IN INCHES (IH>0).                               CNTR0840
                                                                       CNTR0850
   10) LTG IS A LOGICAL*1 ARRAY DIMENSIONED LTG(3) WHERE:              CNTR0860
                                                                       CNTR0870
       A) LTG(1)=.TRUE. REQUESTS LABELLING OF ALL EXTERIOR CONTOURCNTR0880
                    SEGMENTS AND THOSE INTERIOR CONTOUR SEGMENTS       CNTR0890
                    WHICH REPRESENT A LOCAL MAXIMUM.                   CNTR0900
                                                                       CNTR0910
          LTG(1)=.FALSE. OMITS LABELLING OPTION.                       CNTR0920
                                                                       CNTR0930
       B) LTG(2)=.TRUE. REQUESTS TIC MARKS AND CORRESPONDING SCALECNTR0940
                    VALUES ONE INCH APART ON THE EXTERIOR FRAME OF     CNTR0950
                    THE CONTOUR GRAPH.                                 CNTR0960
                                                                       CNTR0970
          LTG(2)=.FALSE. OMITS "TIC" OPTION.                           CNTR0980
                                                                       CNTR0990
       C) LTG(3)=.TRUE. REQUESTS CONTUR TO SUPERIMPOSE A ONE INCH CNTR1000
                    BY ONE INCH STRAIGHT LINE GRID ON THE CONTOUR      CNTR1010
                    GRAPH.                                             CNTR1020
                                                                       CNTR1030
          LTG(3)=.FALSE. OMITS THE GRID OPTION.                        CNTR1040
                                                                       CNTR1050
  C. ERROR MESSAGES                                                    CNTR1060
                                                                       CNTR1070
    1) "CONTOUR LINE AT LEVEL (E12.5) WAS TERMINATED AT X=(E12.5),CNTR1080
       Y=(E12.5) BECAUSE IT CONTAINED MORE THAN 1799 POINTS." (THECNTR1090
       APPROPRIATE VALUES ARE PRINTED WHERE FORMATS ARE INDICATED)CNTR1100
                                                                       CNTR1110
    2) "WIDTH OF CONTOUR GRAPH ILLLEGAL."  (IW.LE.0)                   CNTR1120
                                                                       CNTR1130
    3) "HEIGHT OF CONTOUR GRAPH ILLEGAL." (IH.LE.0)                    CNTR1140
                                                                       CNTR1150
    4) "DATA MATRIX HAS ONLY ONE LEVEL."  AFTER SCANNING THE DATA CNTR1160
       MATRIX FOR THE HIGHEST AND LOWEST LEVEL ENTRIES, CONTUR         CNTR1170
       FINDS THAT THE MATRIX TO BE CONTOURED CONTAINS THE SAME         CNTR1180
       LEVEL VALUE IN ALL ENTRIES.                                     CNTR1190
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                                                                     CNTR1200
      5) "NUMBER OF LEVELS REQUESTED=0."  (NL=0)                     CNTR1210
                                                                     CNTR1220
      6) "NO GRAPH WILL BE PRODUCED." THIS MESSAGE FOLLOWS 2)-5)     CNTR1230
         ABOVE.                                                      CNTR1240
                                                                     CNTR1250
      7) " IW PARAMETER GREATER THAN 9. CONTUR WILL SET IW=9."       CNTR1260
         PROCESSING CONTINUES WITH IW=9.                             CNTR1270
                                                                     CNTR1280
4. SUBROUTINES USED                                                  CNTR1290
                                                                     CNTR1300
       THE SUBROUTINES DESCRIBED IN "THE PLOTTING PACKAGE FOR NPGS   CNTR1310
   IBM 360/67" ARE USED TO DRAW THE CONTOUR GRAPH.  SUBROUTINES      CNTR1320
   WHICH FIND THE POINTS TO BE PLOTTED WERE PROVIDED BY              CNTR1330
   DR. M.O. DAYHOFF OF THE NATIONAL BIOMEDICAL RESEARCH FOUNDATION,  CNTR1340
   SILVER SPRING, MARYLAND.                                          CNTR1350
                                                                     CNTR1360


       SUBROUTINE PLOTT DRAWS THE INTERIOR AND EXTERIOR CONTOUR      CNTR1370
   SEGMENTS AND LABELS (IF REQUESTED) THE EXTERIOR CONTOUR           CNTR1380
   SEGMENTS.  CONTUR DOES THE LABELLING OF INTERIOR SEGMENTS         CNTR1390
   WHICH REPRESENT LOCAL MAXIMA.                                     CNTR1400
                                                                     CNTR1410
5. RESTRICTIONS                                                      CNTR1420
                                                                     CNTR1430
   A) INPUT                                                          CNTR1440
                                                                     CNTR1450
      1) 1.LE.IW.LE.9                                                CNTR1460
                                                                     CNTR1470
      2) IH.GE.1                                                     CNTR1480
                                                                     CNTR1490
      3) WHENEVER NL IS POSITIVE THE DATA MATRIX IS NOT SCANNED FOR CNTR1500
         THE MINIMUM AND MAXIMUM LEVELS; CONSEQUENTLY THE USER IS    CNTR1510
         CAUTIONED AGAINST THE POSSIBILITY THAT NO GRAPH WILL BE     CNTR1520
         PRODUCED IF                                                 CNTR1530
                                                                     CNTR1540
         A) ALL ENTRIES IN THE DATA MATRIX ARE EQUAL                 CNTR1550
                                                                     CNTR1560
         B) ENTRIES IN THE DATA MATRIX ARE ALL BELOW OR ALL ABOVE    CNTR1570
            THE REQUESTED LEVELS.                                    CNTR1580
                                                                     CNTR1590
   B) OUTPUT                                                         CNTR1600
                                                                     CNTR1610
      1) ACCURACY IS LIMITED BY THE LINEAR INTERPOLATION PROCESS     CNTR1620
         USED IN FINDING THE VALUES OF THE POINTS ALONG CONTOUR      CNTR1630
         SEGMENTS. IT IS ALSO LIMITED BY THE RESOLUTION OF THE       CNTR1640
         OFFLINE PLOTTER; I.E., .01 INCH IN BOTH THE X AND Y         CNTR1650
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         DIRECTIONS.                                                  CNTR1660
                                                                      CNTR1670
      2) THE X-SCALE VALUES ALONG THE TIC MARKS ARE 1.0.LE.X.LE.N.    CNTR1680
         THE Y-SCALE VALUES ARE 1.0.LE.Y.LE.M.                        CNTR1690
                                                                      CNTR1700
      3) ONLY UP TO 20 INTERIOR SEGMENTS WHICH REPRESENT              CNTR1710
         MAXIMA ARE LABELLED.                                         CNTR1720
                                                                      CNTR1730
   6. STORAGE REQUIREMENTS                                            CNTR1740
                                                                      CNTR1750
        CONTUR AND ALL ITS SUBORDINATE SUBROUTINES REQUIRE 54,570     CNTR1760
        BYTES OF CORE.                                                CNTR1770
                                                                      CNTR1780
   7. HARDWARE CONFIGURATION                                          CNTR1790
                                                                      CNTR1800
     A) IBM 360/67EQUIPMENT CONFIGURATION (INCLUDING SPOOLING DISKS,  CNTR1810
        ETC.) WITH APPROPRIATE SYSOUT AND SYSIN UNITS.                CNTR1820
                                                                      CNTR1830
     B) CALCOMP MODEL 765 PLOTTER                                     CNTR1840
                                                                      CNTR1850
   8. REFERENCES                                                      CNTR1860
                                                                      CNTR1870
     A) DAYHOFF,M.O.,"A CONTOUR-MAP PROGRAM FOR X-RAY CRYSTALLOGRAPHY"CNTR1880
        COMMUNICATIONS OF ASSOCIATION FOR COMPUTING MACHINERY,        CNTR1890
        OCTOBER 1963                                                  CNTR1900
                                                                      CNTR1910
     B) JOHNSON, PATRICIA C.,"PLOTTING PACKAGE FOR NPGS IBM 360/67",  CNTR1920
        TECHNICAL NOTE NO. 0211-03, FEBRUARY 1969                     CNTR1930
                                                                      CNTR1940
     C) HILLEARY, R.R., "J7-NPG-CONTOUR (F-60)", SEPTEMBER 1964.      CNTR1950
                                                                      CNTR1960
   9. MATHEMATICAL METHOD                                             CNTR1970
                                                                      CNTR1980
        THE ALGORITHM USED IN FINDING THE CONTOURS IS DEFINED IN      CNTR1990
        REFERENCE A).                                                 CNTR2000
......................................................................CNTR2010

      SUBROUTINE CONTUR(AM,M,N,MX,CL,NL,TITLE,IW,IH,LTG)              CNTR2020
      REAL*8 TITLE(1)                                                 CNTR2030
      REAL*8 WIDTH/'WIDTH'/,HEIGHT/'HEIGHT'/,WHICH                    CNTR2040
      DIMENSION AM(MX,1),CL(1)                                        CNTR2050
      DIMENSION           REC(900),  X(1800), Y(1800)                 CNTR2060
      DIMENSION IPT(3,3),INX(8),INY(8)                                CNTR2070
      COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,      CNTR2080
     1             PY,REC,CV,     IPT,INX,INY,DL,RA,THE               CNTR2090
      COMMON /INTFAC/ X,Y                                             CNTR2100
      DIMENSION DITSX(5),DITSY(5)                                     CNTR2110
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      LOGICAL*1 LTG(1),MINUS,LABL                                       CNTR2120
      CCMMON/TABL/ TABC(20,6),JC                                        CNTR2130
      COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSDX,CITSDY,ICIR,LABL,MINUS CNTR2140
      JC=0                                                              CNTR2150
      LABL=LTG(1)                                                       CNTR2160
      CHECK IW PARAMETER                                                CNTR2170
      WHICH=WIDTH                                                       CNTR2180
      IF(IW) 1,1,2                                                      CNTR2190
    1 WRITE(6,60) WHICH                                                 CNTR2200
   60 FCRMAT('0',T7,A8,'CF CONTOUR GRAPH ILLEGAL.')                     CNTR2210
   71 WRITE(6,64)                                                       CNTR2220
   64 FORMAT('0',T7,'NO GRAPH WILL BE PRODUCED.')                       CNTR2230
      RETURN                                                            CNTR2240
      CHECK IF IW IS TOO WIDE                                           CNTR2250
    2 IF(IW-9) 3,3,40                                                   CNTR2260
   40 WRITE(6,61)                                                       CNTR2270
   61 FORMAT('0',T7,'IW PARAMETER GREATER THAN 9. CCNTUR WILL SET IW=9.'CNTR2280
     1)                                                                 CNTR2290
      IW=9                                                              CNTR2300
      NOW CHECK IH PARAMETER                                            CNTR2310
    3 IF(IH) 4,4,5                                                      CNTR2320
    4 WFICH=HEIGHT                                                      CNTR2330
      GO TO 1                                                           CNTR2340
    5 DITSDX=(N-1.0)/IW                                                 CNTR2350
      DITSDY=(-1.0+M)/IH                                                CNTR2360
      XMIN=1.0                                                          CNTR2370
      YMIN=-M                                                           CNTR2380
      SLOPEX=1.0/DITSDX                                                 CNTR2390
      SLCPEY=1.0/DITSDY                                                 CNTR2400
      DITSX(1)=1.0                                                      CNTR2410
      DITSX(4)=1.0                                                      CNTR2420
      DITSX(5)=1.0                                                      CNTR2430
      DITSX(2)=N                                                        CNTR2440
      DITSX(3)=N                                                        CNTR2450
      DITSY(1)=-1.0                                                     CNTR2460
      DITSY(2)=-1.0                                                     CNTR2470
              DITSY(5)=-1.0                                             CNTR2480
      DITSY(3)=-M                                                       CNTR2490
      DITSY(4)=-M                                                       CNTR2500
      DC 2011 I=1,5                                                     CNTR2510
      DITSX(I)=SLOPEX*(DITSX(I)-XMIN)                                   CNTR2520
 2011 DITSY(I)=SLOPEY*(DITSY(I)-YMIN)                                   CNTR2530
      STARTP=(9.0-IW)/2.0                                               CNTR2540
      CALL PLOTS                                                        CNTR2550
      CALL PLOT(STARTP,0.0,-3)                                          CNTR2560
      CALL LINE(DITSX,DITSY,5,1,1)                                      CNTR2570
      DITSX(1)=DITSX(1)-.5                                              CNTR2580
      DITSX(5)=DITSX(1)                                                 CNTR2590
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     DITSX(4)=DITSX(4)-.5                                             CNTR2600
     DITSX(2)=DITSX(2)+.5                                             CNTR2610
     DITSX(3)=DITSX(3)+.5                                             CNTR2620
     DITSY(1)=DITSY(1)+.5                                             CNTR2630
     DITSY(5)=DITSY(1)                                                CNTR2640
     DITSY(2)=DITSY(2)+.5                                             CNTR2650
     DITSY(3)=DITSY(3)-.5                                             CNTR2660
     DITSY(4)=DITSY(4)-.5                                             CNTR2670
     CALL LINE(DITSX,DITSY,5,1,1)                                     CNTR2680
     SLOPEX=1.0/DITSDX                                                CNTR2690
     SLOPEY=1.0/DITSDY                                                CNTR2700
     IENDX=SLOPEX*N+1                                                 CNTR2710
     IENDY=SLOPEY*M+1                                                 CNTR2720
     IF(.NOT.LTG(2)) GO TO 34                                         CNTR2730
     DRAW TIC MARKS ON OUTER FRAME                                    CNTR2740
     START ON LEFT EDGE GOING DOWNWARD                                CNTR2750
     IFLAG=0                                                          CNTR2760
     ZINGX=-.1                                                        CNTR2770
     ZINGY=0.0                                                        CNTR2780
     ZX=0.0                                                           CNTR2790
     ZY=-1.0                                                          CNTR2800
     CX=DITSX(1)                                                      CNTR2810
     CY=DITSY(1)-.5                                                   CNTR2820
     IEND=IENDY                                                       CNTR2830
2222 IFLAG=IFLAG+1                                                    CNTR2840
     DO 2022 I=1,IEND                                                 CNTR2850
     CALL PLOT(CX,CY,3)                                               CNTR2860
     COORDX=CX+ZINGX                                                  CNTR2870
     COORDY=CY+ZINGY                                                  CNTR2880
     CALL PLOT(COORDX,COORDY,2)                                       CNTR2890
     CX=CX+ZX                                                         CNTR2900
2022 CY=CY+ZY                                                         CNTR2910
     GO TO (21,22,23,24),IFLAG                                        CNTR2920
     NOW DO THE RIGHT EDGE GOING DOWNWARD                             CNTR2930
  21 ZINGX=.1                                                         CNTR2940
     CX=DITSX(2)                                                      CNTR2950
     CY=DITSY(2)-.5                                                   CNTR2960
     GO TO 2222                                                       CNTR2970
     NOW DO TOP EDGE                                                  CNTR2980
  22 ZINGX=0.0                                                        CNTR2990
     ZINGY=.1                                                         CNTR3000
     ZX=1.0                                                           CNTR3010
     ZY=0.0                                                           CNTR3020
     CX=DITSX(1)+.5                                                   CNTR3030
     CY=DITSY(1)                                                      CNTR3040
     IEND=IENDX                                                       CNTR3050
     GO TO 2222                                                       CNTR3060
     NOW DO THE BOTTOM EDGE                                           CNTR3070
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   23 ZINGY=-.1                                                          CNTR3080
      CX=DITSX(4)+.5                                                     CNTR3090
      CY=DITSY(4)                                                        CNTR3100
      ZINGY=-.1                                                          CNTR3110
      GO TO 2222                                                         CNTR3120
      NOW LABEL TIC MARKS                                                CNTR3130
      DO X-DIRECTION FIRST, TOP EDGE                                     CNTR3140
      POSITION PEN                                                       CNTR3150
   24 DELTAX=DITSDX                                                      CNTR3160
      IFLAG=0                                                            CNTR3170
      ZX=1.0                                                             CNTR3180
      ZY=0.0                                                             CNTR3190
      CX=DITSX(1)+.35                                                    CNTR3200
      CY=DITSY(1)+.12                                                    CNTR3210
 3033 IFLAG=IFLAG+1                                                      CNTR3220
      XZERO=1.0                                                          CNTR3230
      DO 3333 I=1,IEND                                                   CNTR3240
      CALL NUMBER(CX,CY,.07,XZERO,0.0,1)                                 CNTR3250
      CX=CX+ZX                                                           CNTR3260
      CY=CY+ZY                                                           CNTR3270
 3333 XZERO=XZERO+DELTAX                                                 CNTR3280
      GO TO (31,32,33,34),IFLAG                                          CNTR3290
      LABEL BOTTOM EDGE TIC MARKS                                        CNTR3300
   31 CX=DITSX(4)+.35                                                    CNTR3310
      CY=DITSY(4)-.19                                                    CNTR3320
      GO TO 3033                                                         CNTR3330
      LABEL LEFT EDGE OF TIC MARKS                                       CNTR3340
   32 CX=DITSX(4)-.4                                                     CNTR3350
      CY=DITSY(4)+.46                                                    CNTR3360
      DELTAX=DITSDY                                                      CNTR3370
      IEND=IENDY                                                         CNTR3380
      ZX=0.0                                                             CNTR3390
      ZY=1.0                                                             CNTR3400
      GO TO 3033                                                         CNTR3410
      NOW LABEL RIGHT EDGE TIC MARKS                                     CNTR3420
   33 CX=DITSX(3)+.12                                                    CNTR3430
      CY=DITSY(3)+.46                                                    CNTR3440
      GO TO 3033                                                         CNTR3450
      CHECK IF GRID DESIRED                                              CNTR3460
   34 IF(.NOT.LTG(3)) GO TO 35                                           CNTR3470
      DRAW INCH BY INCH GRID                                             CNTR3480
      IEND=IENDX-2                                                       CNTR3490
      POSITION PEN                                                       CNTR3500
      IFLAG=0                                                            CNTR3510
      CX=DITSX(1)+.5                                                     CNTR3520
      CY=DITSY(1)-.5                                                     CNTR3530
      COORDX=0.0                                                         CNTR3540
      COORDY=-IH                                                         CNTR3550
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      DX=1.0                                                              CNTR3560
      DY=0.0                                                              CNTR3570
 4044 DO 4444  I=1,IEND                                                   CNTR3580
      CX=CX+DX                                                            CNTR3590
      CY=CY+DY                                                            CNTR3600
      CALL  PLOT (CX,CY,3)                                                CNTR3610
      ZX=CX+CCORDX                                                        CNTR3620
      ZY=CY+COORDY                                                        CNTR3630
 4444 CALL  PLOT(ZX,ZY,2)                                                 CNTR3640
      IF(IFLAG) 35,42,35                                                  CNTR3650
   42 IFLAG=1                                                             CNTR3660
      IEND=IENDY-2                                                        CNTR3670
      CY=DITSY(4)+.5                                                      CNTR3680
      CX=DITSX(4)+.5                                                      CNTR3690
      CCORDX=IW                                                           CNTR3700
      CCORDY=0.0                                                          CNTR3710
      DX=0.0                                                              CNTR3720
      DY=1.0                                                              CNTR3730
      GO  TO  4044                                                        CNTR3740
   35 CCNTINUE                                                            CNTR3750
      NLEV=NL                                                             CNTR3760
      CHECK  IF  CONTUR  IS  TC   COMPUTE  LEVELS                         CNTR3770
      IF(NLEV) 6,7,11                                                     CNTR3780
      NL  NEGATIVE   MEANS  CONTCUR  MUST  CCMPUTE  LEVELS                CNTR3790
      SCAN  MATRIX  FOR  LOWEST  AND  HIGHEST  LEVELS                     CNTR3800
    6 NLEV=-NLEV                                                          CNTR3810
      FMIN=AM(1,1)                                                        CNTR3820
      FMAX=FMIN                                                           CNTR3830
      DC  9  I=1,M                                                        CNTR3840
      DO  9  J=1,N                                                        CNTR3850
      IF(AM(I,J).LT.FMIN)  FMIN=AM(I,J)                                   CNTR3860
      IF(AM(I,J).GT.FMAX)  FMAX=AM(I,J)                                   CNTR3870
    9 CONTINUE                                                            CNTR3880
      CHECK  IF  MIN  AND  MAX  ARE  EQUAL                                CNTR3890
      IF(FMIN.GE.FMAX)  GO  TO  300                                       CNTR3900
      DELTAL=(FMAX-FMIN)/(NLEV-1)                                         CNTR3910
      SET  UP  CL  ARRAY                                                  CNTR3920
      DO  10  I=1,NLEV                                                    CNTR3930
   10 CL(I)=FMIN+(I-1)*DELTAL                                             CNTR3940
   11 DO  20  I=1,NLEV                                                    CNTR3950
   20 CALL  SCAN(AM,M,N,MX,CL(I))                                         CNTR3960
      IF(.NOT.LABL)  GO  TO  778                                          CNTR3970
      IF(JC.EQ.0)  GO  TO  778                                            CNTR3980
      DO  777  I=1,JC                                                     CNTR3990
      COORDX=TABC(I,4)                                                    CNTR4000
      COORDY=TABC(I,5)                                                    CNTR4010
      CLEV=TABC(I,6)                                                      CNTR4020
      CALL  NUMBER(COORDX,COORDY,.07,CLEV,0.0,1)                          CNTR4030
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```
777 CONTINUE
778 CALL SYMBOL(-STARTP,IH+1.0,.21,TITLE(7),0.0,48)
    CALL SYMBOL(-STARTP,IH+1.5,.21,TITLE(1),0.0,48)
    CALL PLOT(-STARTP,IH+5.0,-3)
    CALL PLOTE
    RETURN
300 WRITE(6,62) FMIN
 62 FORMAT('0',T7,'DATA MATRIX HAS ONLY ONE LEVEL=',E15.3)
    GO TO 71
  7 WRITE(6,63)
 63 FORMAT('0',T7,'NUMBER OF LEVELS REQUESTED=0.')
    GO TO 71
    END


    SUBROUTINE SCAN(AM,M,N,MX,CL)
THIS PROGRAM IS WRITTEN BY M.O.DAYHOFF
    DIMENSION AM(MX,1 ),REC(900),  X(1800), Y(1800)
    DIMENSION IPT(3,3),INX(8),INY(8)
    COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,
   1                PY,REC,CV,     IPT,INX,INY,DL,RA,THE
    COMMON /INTFAC/ X,Y
    LOGICAL *1 LABL,MINUS
    COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSDX,DITSDY,IDIR,LABL,MINUS
    D=0.
    R=1.
    TH = 1.570796
    NP=0
    DL=D
    RA=R
    THE=TH
    MT=N
    NT=M
    CV=CL
    IF(IZW-120631) 1,3,1
  1 IPT(1,1)=8
    IPT(1,2)=1
    IPT(1,3)=2
    IPT(2,1)=7
    IPT(2,3)=3
    IPT(3,1)=6
    IPT(3,2)=5
    IPT(3,3)=4
    INX(1)=-1
    INX(2)=-1
    INX(3)=0
    INX(4)=1
    INX(5)=1
```

```
      INX(6)=1                                                          CNTR4500
      INX(7)=0                                                          CNTR4510
      INX(8)=-1                                                         CNTR4520
      INY(1)=0                                                          CNTR4530
      INY(2)=1                                                          CNTR4540
      INY(3)=+1                                                         CNTR4550
      INY(4)=+1                                                         CNTR4560
      INY(5)=0                                                          CNTR4570
      INY(6)=-1                                                         CNTR4580
      INY(7)=-1                                                         CNTR4590
      INY(8)=-1                                                         CNTR4600
      IZW=120631                                                        CNTR4610
    3 XT=MT                                                             CNTR4620
      DO 58 J=1,900                                                     CNTR4630
   58 REC(J)=0                                                          CNTR4640
      ISS=0                                                             CNTR4650
    2 MT1=MT-1                                                          CNTR4660
      IDIR=1                                                            CNTR4670
      DO 110 I=1,MT1                                                    CNTR4680
      IF(AM(1,I)-CV) 55,110,110                                         CNTR4690
   55 IF(AM(1,I+1)-CV) 110,57,57                                        CNTR4700
   57 IX=I+1                                                            CNTR4710
      IY=1                                                              CNTR4720
      IDX=-1                                                            CNTR4730
      IDY=0                                                             CNTR4740
      CALL TRACE (AM,MX)                                                CNTR4750
  110 CONTINUE                                                          CNTR4760
      NT1=NT-1                                                          CNTR4770
      IDIR=2                                                            CNTR4780
      DO 20 I=1,NT1                                                     CNTR4790
      IF(AM(I,MT)-CV) 15,20,20                                          CNTR4800
   15 IF(AM(I+1,MT)-CV) 20,17,17                                        CNTR4810
   17 IX=MT                                                             CNTR4820
      IY=I+1                                                            CNTR4830
      IDX=0                                                             CNTR4840
      IDY=-1                                                            CNTR4850
      CALL TRACE (AM,MX)                                                CNTR4860
   20 CONTINUE                                                          CNTR4870
      IDIR=3                                                            CNTR4880
   22 DO 30 I=1,MT1                                                     CNTR4890
      MT2=MT+1-I                                                        CNTR4900
      IF(AM(NT,MT2)-CV) 25,30,30                                        CNTR4910
   25 IF(AM(NT,MT2-1)-CV) 30,27,27                                      CNTR4920
   27 IX=MT2-1                                                          CNTR4930
      IY=NT                                                             CNTR4940
      IDX=1                                                             CNTR4950
      IDY=0                                                             CNTR4960
      CALL TRACE (AM,MX)                                                CNTR4970
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 30 CCNTINUE                                                         CNTR4980
    IDIR=4                                                           CNTR4990
    DO 40 I=1,NT1                                                    CNTR5000
    NT2=NT+1-I                                                       CNTR5010
    IF(AM(NT2,1)-CV) 35,40,40                                        CNTR5020
 35 IF(AM(NT2-1,1)-CV) 40,37,37                                      CNTR5030
 37 IX=1                                                             CNTR5040
    IY=NT2-1                                                         CNTR5050
    IDX=0                                                            CNTR5060
    IDY=1                                                            CNTR5070
    CALL TRACE (AM,MX)                                               CNTR5080
 40 CCNTINUE                                                         CNTR5090
    IDIR=5                                                           CNTR5100
    ISS=1                                                            CNTR5110
    NT1=NT-1                                                         CNTR5120
    MT1=MT-1                                                         CNTR5130
    DC 10 J=2,NT1                                                    CNTR5140
    DO 10 I=1,MT1                                                    CNTR5150
    IF(AM(J,I)-CV)5,10,10                                            CNTR5160
  5 IF(AM(J,I+1)-CV) 10,7,7                                          CNTR5170
  7 COM=100*(I+1)+J                                                  CNTR5180
    IF (NP) 12,11,12                                                 CNTR5190
 12 DC 9 ID= 1,NP                                                    CNTR5200
    IF (REC(ID)-COM) 9,10,9                                          CNTR5210
  9 CONTINUE                                                         CNTR5220
 11 IX= I+1                                                          CNTR5230
    IY=J                                                             CNTR5240
    IDX=-1                                                           CNTR5250
    IDY=0                                                            CNTR5260
    CALL TRACE (AM,MX)                                               CNTR5270
 10 CCNTINUE                                                         CNTR5280
    RETURN                                                           CNTR5290
    END                                                              CNTR5300

    SUBROUTINE TRACE (AM,MY)                                         CNTR5310
    DIMENSION AM(MY,1 ),REC(900),  X(1800), Y(1800)                  CNTR5320
    DIMENSICN IPT(3,3), INX(8),INY(8)                                CNTR5330
    COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,       CNTR5340
   1                PY,REC,CV,    IPT,INX,INY,DL,RA,THE              CNTR5350
    COMMON /INTFAC/ X,Y                                              CNTR5360
    PY=0.0                                                           CNTR5370
    RC=  COS (THE)*RA                                                CNTR5380
    RS=  SIN (THE)*RA                                                CNTR5390
501 JT=0                                                             CNTR5400
    N=0                                                              CNTR5410
    IXC=IX                                                           CNTR5420
    IYO=IY                                                           CNTR5430
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      ISX=IDX+2                                                         CNTR5440
      ISY=IDY+2                                                         CNTR5450
      IS=IPT(ISX,ISY)                                                   CNTR5460
      JTB=0                                                             CNTR5470
      ISO=IS                                                            CNTR5480
      IF(ISO-8)18,18,17                                                 CNTR5490
   17 ISO=ISO-8                                                         CNTR5500
   18 IT=0                                                              CNTR5510
    5 CONTINUE                                                          CNTR5520
      CALL CALC  (AM,MY)                                                CNTR5530
      NZ=N                                                              CNTR5540
      N=NZ                                                              CNTR5550
      IF (IT+JT-1) 49,49,47                                             CNTR5560
   47 XS=X(N-1)                                                         CNTR5570
      YS=Y(N-1)                                                         CNTR5580
      X(N-1)=X(N)                                                       CNTR5590
      Y(N-1)=Y(N)                                                       CNTR5600
      X(N)=XS                                                           CNTR5610
      Y(N)=YS                                                           CNTR5620
   49 IS=IS+1                                                           CNTR5630
      JT=IT                                                             CNTR5640
    9 IF (IS-9) 8,7,7                                                   CNTR5650
    7 IS=IS-8                                                           CNTR5660
    8 IDX=INX(IS)                                                       CNTR5670
      IDY=INY(IS)                                                       CNTR5680
      IX2=IX+IDX                                                        CNTR5690
      IY2=IY+IDY                                                        CNTR5700
      JTB=JTB+1                                                         CNTR5710
      IF (JTB-1799) 51,51,308                                           CNTR5720
  308 PRINT               103,CV,X(N),Y(N)                              CNTR5730
  103 FORMAT(1H0,23HA CONTOUR LINE AT LEVEL,E12.5,21H WAS TERMINATED AT CNTR5740
     1X=,E12.5,3H Y=,E12.5/                                             CNTR5750
     2 48H BECAUSE IT CONTAINED MORE THAN 1799 PLOT POINTS  )           CNTR5760
      RETURN                                                            CNTR5770
                                                                        CNTR5780
    SHOULD TEST HERE FOR MAXIMUM NUMBER OF PLOTTABLE POINTS IN SEGMENT. CNTR5790
   51 CONTINUE                                                          CNTR5800
      IF (ISS) 10,10,20                                                 CNTR5810
   20 IF(IX-IXO) 12,21,12                                               CNTR5820
   21 IF(IY-IYO) 12,22,12                                               CNTR5830
   22 IF(IS-ISO) 12,23,12                                               CNTR5840
   23 CONTINUE                                                          CNTR5850
      CALL CALC  (AM,MY)                                                CNTR5860
      GO TO 73                                                          CNTR5870
   10 IF(IX2) 13,50,13                                                  CNTR5880
   13 IF (IX2-MT) 19,19,50                                              CNTR5890
   19 IF (IY2) 11,50,11                                                 CNTR5900
   11 IF (IY2-NT) 12,12,50                                              CNTR5910
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```
 12 IF(CV-AM(IY2,IX2)) 206,206,5
206 IF (IDX**2+IDY**2-1) 213,6,213
213 DCP=(AM(IY,IX)+AM(IY,IX2)+AM(IY2,IX)+AM(IY2,IX2))/4.0
    IF (DCP-CV) 5,217,217
217 IF (INX(IS-1)) 214,215,214
214 IX=IX+IDX
    IDX=-IDX
    PY=2.0
    CALL CALC  (AM,MY)
    IX=IX+IDX
    GO TO 6
215 IY=IY+IDY
    IDY=-IDY
    PY=2.0
    CALL CALC  (AM,MY)
    IY=IY+IDY
  6 IF(AM(IY,IX-1)-CV) 306,16,16
306 NP=NP+1
    REC(NP)=100*IX+IY
 16 IS=IS+5
    IX=IX2
    IY=IY2
    GO TO 9
 50 XT=MT
    IF(AM(IY,IX-1)-CV) 307,73,73
307 NP=NP+1
    REC(NP)=100*IX+IY
 73 DO 74 I=1,N
    X(I)=X(I)+RC*Y(I)
 74 Y(I)=RS*Y(I)
    CALL PLOTT(N,CV)
    RETURN
    END


    SUBROUTINE CALC(AM,MY)
    DIMENSION AM(MY,1 ),REC(900),  X(1800), Y(1800)
    DIMENSION IPT(3,3),INX(8),INY(8)
    COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,
   1                PY,REC,CV,     IPT,INX,INY,DL,RA,THE
    COMMON /INTFAC/ X,Y
    IT=0
    N=N+1
    IF (IDX**2 + IDY**2 -1) 20,1,20
  1 IF (IDX) 10,2,10
  2 X(N)=IX
    Z=IY
    IY2=IY+IDY
```

```
      DY=IDY                                                            CNTR6380
   41 Y(N)=((AM(IY,IX)-CV)/(AM(IY,IX)-AM(IY2,IX)))*DY+Z                 CNTR6390
      RETURN                                                            CNTR6400
   10 Y(N)=IY                                                           CNTR6410
      W=IX                                                              CNTR6420
      DX=IDX                                                            CNTR6430
      IX2=IX+IDX                                                        CNTR6440
   44 X(N)=((AM(IY,IX)-CV)/(AM(IY,IX)-AM(IY,IX2)))*DX+W                 CNTR6450
      RETURN                                                            CNTR6460
   20 IX2=IX+IDX                                                        CNTR6470
      IY2=IY+IDY                                                        CNTR6480
      W=IX                                                              CNTR6490
      Z=IY                                                              CNTR6500
      DX=IDX                                                            CNTR6510
      DY=IDY                                                            CNTR6520
      DCP=(AM(IY,IX)+AM(IY,IX2)+AM(IY2,IX)+AM(IY2,IX2))/4.0             CNTR6530
      IF (PY-2.0) 24,21,24                                              CNTR6540
   24 IF (DCP-CV) 21,21,25                                              CNTR6550
   21 AL=AM(IY,IX)-DCP                                                  CNTR6560
   23 V=.5*(AL+DCP -CV)/AL                                              CNTR6570
   27 X(N)=V*DX+W                                                       CNTR6580
      Y(N)=V*DY+Z                                                       CNTR6590
      PY=0.0                                                            CNTR66C0
      RETURN                                                            CNTR6610
   25 IT=1                                                              CNTR6620
      AL=AM(IY2,IX2)-DCP                                                CNTR6630
   33 V=.5*(AL+DCP-CV)/AL                                               CNTR6640
   28 X(N)=-V*DX+W  + DX                                                CNTR6650
      Y(N)=-V*DY+Z  + DY                                                CNTR6660
      Y(N)=-V*DY+Z  + DY                                                CNTR6670
      RETURN                                                            CNTR6680
      END                                                               CNTR6690


      SUBROUTINE PLOTT(NP,CV)                                           CNTR67C0
      CCMMON/INTFAC/X(1800),Y(1800)                                     CNTR6710
      LOGICAL*1 MINUS,LABL                                              CNTR6720
      COMMON/TABL/ TABC(20,6),JC                                        CNTR6730
      COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSDX,DITSDY,IDIR,LABL,MINUS CNTR6740
      SCALE PCINTS FOR PLOT ROUTINE                                     CNTR6750
      DC 100 I=1,NP                                                     CNTR6760
      X(I)=SLOPEX*(X(I)-XMIN)                                           CNTR6770
  100 Y(I)=SLCPEY*(-Y(I)-YMIN)                                          CNTR6780
      CALL LINE(X,Y,NP,1,1)                                             CNTR6790
      IF(.NOT.LABL) RETURN                                              CNTR6800
      SHCULD ADJUSTMENT CF PEN LOCATION BE MADE FOR LABELLING CURVE?    CNTR6810
      DIR=0.0                                                           CNTR6820
      GC TO (1,2,3,4,6), IDIR                                           CNTR6830
```

```
    1 DIR=90.                                                            CNTR6840
    2 CCORDX=X(1 )                                                       CNTR6850
      COORDY=Y(1 )                                                       CNTR6860
    5 CALL NUMBER(COORDX,COORDY,.07,CV,DIR,1)                            CNTR6870
      RETURN                                                             CNTR6880
      MOVE PEN DOWN ONE HALF INCH                                        CNTR6890
    3 DIR=90.                                                            CNTR6900
      CCORDX=X(1 )                                                       CNTR6910
      COORDY=Y(1 )-.3                                                    CNTR6920
      GC TO 5                                                            CNTR6930
      MOVE PEN TO THE LEFT                                               CNTR6940
    4 COORDX=X(1 )-.3                                                    CNTR6950
      CCORDY=Y(1 )                                                       CNTR6960
      GO TO 5                                                            CNTR6970
      SEARCH FOR XMAX,XMIN,YMAX,YMIN,AND SAVE YMINX                      CNTR6980
    6 XMAX=X(1)                                                          CNTR6990
      SMIN=XMAX                                                          CNTR7000
      YMINX=Y(1)                                                         CNTR7010
      YMAX=YMINX                                                         CNTR7020
      VMIN=YMINX                                                         CNTR7030
      DO 200 I=2,NP                                                      CNTR7040
      IF(X(I).GT.XMAX) XMAX=X(I)                                         CNTR7050
      IF(Y(I).LT.VMIN) VMIN=Y(I)                                         CNTR7060
      IF(Y(I).GT.YMAX) YMAX=Y(I)                                         CNTR7070
      IF(X(I).GE.SMIN) GO TO 200                                         CNTR7080
      SMIN=X(I)                                                          CNTR7090
      YMINX=Y(I)                                                         CNTR7100
  200 CONTINUE                                                           CNTR7110
      JC=NUMBER OF ENTRIES IN TABC                                       CNTR7120
      IF(JC) 400,500,400                                                 CNTR7130
      SEARCH TABLE TO SEE IF THIS IS INTERIOR TC ANCTHER INTERIOR SEGMENCNTR7140
  400 DC 900 I=1,JC                                                      CNTR7150
      IF(XMAX.LT.TABC(I,1).AND.YMAX.LT.TABC(I,2).AND.VMIN.GT.TABC(I,3). CNTR7160
     1AND.SMIN.GT.TABC(I,4)) GO TO 700                                   CNTR7170
  900 CCNTINUE                                                           CNTR7180
      DID NOT FIND THIS CONTOUR TO BE INTERIOR TC ANOTHER                CNTR7190
      CHECK IF EXTERIOR                                                  CNTR7200
      DO 1000 I=1,JC                                                     CNTR7210
      IF(XMAX.GT.TABC(I,1).AND.YMAX.GT.TABC(I,2).AND.VMIN.LT.TABC(I,3). CNTR7220
     1ANC.SMIN.LT.TABC(I,4)) GO TO 800                                   CNTR7230
 100C CCNTINUE                                                           CNTR7240
      THIS CONTOUR SEGMENT WAS NEITHER INTERIOR NCR EXTERICR TC ANOTHER CNTR7250
  500 IF (JC.EQ.20) RETURN                                               CNTR7260
      JC=JC+1                                                            CNTR7270
      MC=JC                                                              CNTR7280
  600 TABC(MC,1)=XMAX                                                    CNTR7290
      TABC(MC,2)=YMAX                                                    CNTR7300
      TABC(MC,3)=VMIN                                                    CNTR7310
```

```
      TABC(MC,4)=SMIN                                                   CNTR7320
      TABC(MC,5)=YMINX                                                  CNTR7330
      TABC(MC,6)=CV                                                     CNTR7340
      RETURN                                                            CNTR7350
      CHECK IF THIS INTERIOR ONE IS OF HIGHER LEVEL                     CNTR7360
  700 IF(CV.LE.TABC(I,6) ) RETURN                                       CNTR7370
 2000 MC=I                                                              CNTR7380
      GO TO 600                                                         CNTR7390
      CHECK IF LEVEL OF THIS EXTERIOR ONE IS HIGHER                     CNTR7400
  800 IF(CV.LT.TABC(I,6)) RETURN                                        CNTR7410
      GO TO 2000                                                        CNTR7420
      END                                                               CNTR7430
```

APPENDIX B

```
***********************************************************************
*                            SUBPROGRAMS                              *
*                      AND RELATED SUBROUTINES                        *
*                                                                     *
***********************************************************************


***********************************************************************
                      PROGRAM FOR INTRPL
     DIMENSION BB(101,20),TH(13),X(101),Y(101),U(60),V(60)
 100 FORMAT (4I10,2F10.5)
 101 FORMAT (F10.5)
 102 FORMAT (T10,I5,2F10.5)
 103 FORMAT (8F10.5)
 105 FORMAT (T10,I5,F10.5)
     READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
     FNP=FLOAT(NP)
     DR=2*RMAX/(FNP-1)
     L=NP-(NP-1)/4
     L2=L/2
     LW=NP-L/2
     N=NP-L
     DO 10 J=1,NT
     READ(5,101) TH(J)
     READ(5,103,END=10)(BB(I,J),I=1,NP)
  10 CONTINUE
  11 DO 110 J=1,NT
     DO 30 I=1,NP
  12 K=I-1
     IF(I.GT.L2) GO TO 15
     Y(I)=BB(I,J)
     X(I)=-RMAX+K*DR
     GO TO 30
5    IF(I.GT.LW) GO TO 20
     LL=I-L2
     U(LL)=-RMAX+K*DR
     GO TO 30
  20 KK=I-N
     Y(KK)=BB(I,J)
     X(KK)=-RMAX +K*DR
```

```
0     CONTINUE
      WRITE(6,103)(X(I),I=1,L)
      WRITE(6,103)(Y(I),I=1,L)
      WRITE(6,103)(U(I),I=1,N)
      CALL INTRPL(L,X,Y,N,U,V)
      WRITE(6,103)(V(I),I=1,N)
*****TO PRINT THE OUTPUT (I.E. Y(1) TO Y(36, V(1), TO V(25),
      Y(37)  TO Y(76)  ), IN A TOTAL 8F10.5 FORMAT, STORE THE
*****TWO VECTORS IN BB(I,J)
      DO 70 I=1,NP
      LL=I-L2
      KK=I-N
      IF(I.GT.L2) GO TO 42
      BB(I,J)=Y(I)
      GC TO 70
   42 IF(I.GT.LW) GO TO 50
      BB(I,J)=V(LL)
      GC TO 70
   5C BB(I,J)=Y(KK)
   70 CONTINUE
      WRITE(6,103) TH(J)
      WRITE(6,103)(BB(I,J),I=1,NP)
      WRITE(7,103) TH(J)
      WRITE(7,103)(BB(I,J),I=1,NP)
10    CONTINUE
      STCP
      END
**********************************************************************

**********************************************************************
                        PROGRAM FOR INTRPL (LINEAR)
      DIMENSION BB(101,20),TH(13),X(101),Y(101),U(60),V(60)
  100 FORMAT (4I10,2F10.5)
  101 FORMAT (F10.5)
  102 FORMAT (T10,I5,2F10.5)
  103 FORMAT (8F10.5)
  105 FCRMAT (T10,I5,F10.5)
      READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
      FNP=FLOAT(NP)
      DR=2*RMAX/(FNP-1)
      L=NP-(NP-1)/4
      L2=L/2
      LW=NP-L/2
      N=NP-L
      N2N=2
      DC 10 J=1,NT
      READ(5,101) TH(J)
```

```
      READ(5,103,END=10)(BB(I,J),I=1,NP)
   10 CONTINUE
   11 DC 110 J=1,NT
      LW1=LW+1
      X(1)=-RMAX+(L2-1)*DR
      X(2)=-RMAX+(L2+N)*DR
      Y(1)=BB(L2,J)
      Y(2)=BB(LW1,J)
      DC 20 I=1,N
      U(I)=-RMAX+(L2-1+I)*DR
   20 CCNTINUE
      WRITE(6,103)X(1),X(2)
      WRITE(6,103)Y(1),Y(2)
      WRITE(6,103)(U(I),I=1,N)
      CALL INTRPL(N2N,X,Y,N,U,V)
      WRITE(6,103)(V(I),I=1,N)
*****TO PRINT THE OUTPUT (I.E. Y(1) TO Y(36, V(1), TO V(25),
      Y(37)  TO Y(76)  ), IN A TOTAL 8F10.5 FORMAT, STORE THE
*****TWO VECTORS IN BB(I,J)
      DC 30 I=1,N
      KBB=L2+I
      BB(KBB,J)=V(I)
   3C CCNTINUE
      WRITE(6,103) TH(J)
      WRITE(6,103)(BB(I,J),I=1,NP)
      WRITE(7,103) TH(J)
      WRITE(7,103)(BB(I,J),I=1,NP)
10    CONTINUE
      STOP
      END
***********************************************************************


***********************************************************************


..................................................................... INTR0010
                                                                      INTR0020


      SUBROUTINE INTRPL        (CATEGORY E2)                          INTR0030
                                                                      INTR0040
      1. IDENTIFICATION:                                              INTR0050
                                                                      INTR0060
         A. NAME: INTERPOLATICN OF A SINGLE VALUEC FUNCTION           INTR0070
                  BASED ON LOCAL PROCEDURES                           INTR0080
                                                                      INTRCC90
         B. PROGRAMMER:  HIROSHI AKIMA                                INTR0100
```

```
                                                                      INTRO0110
   C. IMPLEMENTER: MICHAEL CORCORAN                                   INTRO0120
                                                                      INTRO0130
   D. DATE: MARCH, 1973                                               INTRO0140
                                                                      INTRO0150
2. PURPOSE:                                                           INTRO0160
                                                                      INTRO0170
   A. THE INTRPL SUBROUTINE INTERPOLATES, FROM VALUES OF THE          INTRO0180

      FUNCTION GIVEN AS ORDINATES CF INPUT CATA POINTS IN AN          INTRO0190
      X-Y PLANE AND FOR A GIVEN SET OF X VALUES (ABSCISSAS OF         INTRO0200
      DESIRED POINTS), THE VALUES OF A SINGLE VALUED FUNCTION         INTRO0210
      Y = Y(X).                                                       INTRO0220
                                                                      INTRO0230
3. USAGE:                                                             INTRO0240
                                                                      INTRO0250
   A. CALLING STATEMENT:                                              INTRO0260
                                                                      INTRO0270
      CALL INTRPL(L,X,Y,N,U,V)                                        INTRO0280
                                                                      INTRO0290
      WHERE THE INPUT PARAMETERS ARE:                                 INTRO0300
                                                                      INTRO0310
      1) L  -  THE NUMBER OF INPUT CATA POINTS (MUST BE 2 OR MORE)    INTRO0320
                                                                      INTRO0330
      2) X  -  AN ARRAY OF DIMENSION L STORING THE X VALUES           INTRO0340
               (ABSCISSAS) OF THE INPUT DATA POINTS IN ASCENDING      INTRO0350
               ORDER....X(I+1) > X(I)    (TYPE REAL*4)                INTRO0360
                                                                      INTRO0370
      3) Y  -  AN ARRAY OF DIMENSICN L STCRING THE Y VALUES           INTRO0380
         (ORDINATES) OF THE INPUT DATA POINTS   (TYPE REAL*4)         INTRO0390
                                                                      INTRO0400
      4) N  -  THE NUMBER OF POINTS AT WHICH INTERPOLATION OF TFE     INTRO0410
               Y VALUE (ORDINATE) IS DESIRED  (MUST BE ONE CR MCRE)   INTRO0420
                                                                      INTRO0430
      5) U  -  THE ARRAY OF DIMENSICN N STCRING THE X VALUES          INTRO0440
               (ABSCISSAS) OF DESIRED POINTS   (TYPE REAL*4)          INTRO0450
                                                                      INTRO0460
                                                                      INTRO0470
      AND WHERE THE OUTPUT PARAMETER IS                               INTRO0480
                                                                      INTRO0490
      6) V  -  THE ARRAY OF DIMENSION N WHERE THE INTERPOLATED        INTRO0500
               Y VALUES (ORDINATES) ARE TO BE PLACED                  INTRO0510
                                                                      INTRO0520
   B. ERROR MESSAGES:                                                 INTRO0530
                                                                      INTRO0540
      1)  "***   L = 1 OR LESS.                                       INTRO0550
                L =(I7)          N =(I7)                              INTRO0560
```

```
          ERROR DETECTED IN ROUTINE    INTRPL"  (THE APPROPRIATE     INTR0570
          VALUES ARE PRINTED WHERE FORMATS ARE INDICATED)            INTR0580
                                                                     INTR0590
       2)  "***   N = 0 OR LESS.                                     INTR0600
              L =(I7)          N =(I7)                               INTR0610
          ERROR DETECTED IN ROUTINE    INTRPL"                       INTR0620
                                                                     INTR0630
       3)  "***   IDENTICAL X VALUES.                                INTR0640
              I =(I7)          X(I) =(E12.3)                         INTR0650
              L =(I7)          N =(I7)                               INTR0660
          ERROR DETECTED IN ROUTINE    INTRPL"   ( THE VALUES IN     INTR0670
          THE X ARRAY MUST BE IN STRICT ASCENDING SEQUENCE.)         INTR0680
                                                                     INTR0690
       4)  "***   X VALUES OUT OF SEQUENCE.                          INTR0700
              I =(I7)          X(I) =(E12.3)                         INTR0710
              L =(I7)          I =(I7)                               INTR0720
          ERROR DETECTED IN ROUTINE    INTRPL"  ( X(I) < X(I-1) FOR  INTR0730
                                                  SOME I BETWEEN     INTR0740
                                                  2 AND L. )         INTR0750
                                                                     INTR0760
   4. MODE OF ARITHMETIC:                                            INTR0770
                                                                     INTR0780
      SINGLE PRECISION                                               INTR0790
                                                                     INTR0800
   5. REMARKS:                                                       INTR0810
                                                                     INTR0820
      A. WHEN THE FUNCTION TO BE INTERPOLATED REPRESENTS A PERIODIC  INTR0830

        FUNCTION AND A SET OF L DATA POINTS COVERS A WHOLE PERIOD,   INTR0840
        TWO ADDITIONAL DATA POINTS SHOULD BE ADDED AT EACH END AND   INTR0850
        A SET OF L+4 DATA POINTS SHOULD BE GIVEN AS THE INPUT DATA   INTR0860
        POINTS TO THIS SUBROUTINE.                                   INTR0870
                                                                     INTR0880
      B. CORE REQUIREMENT FOR INTRPL:  2968 BYTES.                   INTR0890
                                                                     INTR0900
      C. NO SUBROUTINES OR FUNCTION SUBPROGRAMS ARE REQUIRED.        INTR0910
                                                                     INTR0920
      D. FOR THE CONVENIENCE OF THE NPS USER, THE ORIGINAL FORTRAN   INTR0930
        PROGRAM WAS MODIFIED SLIGHTLY. AN UNNECESSARY INPUT          INTR0940
        PARAMETER - IU, WHICH DESIGNATED THE OUPUT DEVICE NUMBER     INTR0950
        FOR ERROR MESSAGES FROM INTRPL, WAS ELIMINATED FROM THE      INTR0960
        PARAMETER LIST, AND THE FORTRAN CODE WAS MODIFIED TO CHANNEL INTR0970
        ALL ERROR MESSAGES TO THE LINE PRINTER AUTOMATICALLY.        INTR0980
                                                                     INTR0990
   6. METHOD:                                                        INTR1000
                                                                     INTR1010
        THIS ROUTINE IS DEVISED IN SUCH A WAY THAT A CURVE DWAWN     INTR1020
```

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        THROUGH BOTH THE GIVEN AND INTERPOLATED POINTS WILL APPEAR    INTR1030
        SMOOTH AND NATURAL, FREE OF UNNATURAL WIGGLES.  IT IS BASED   INTR1040
        ON A PIECEWISE FUNCTION COMPOSED OF A SET OF POLYNOMIALS,     INTR1050
        EACH OF DEGREE THREE, AT MOST, AND APPLICABLE TO SUCCESSIVE   INTR1060
        INTERVALS OF THE GIVEN POINTS.  IN THIS METHOD, THE SLOPE OF  INTR1070
        THE CURVE IS DETERMINED AT EACH GIVEN POINT LOCALLY, AND      INTR1080
        EACH POLYNOMIAL REPRESENTING A PORTION OF THE CURVE BETWEEN   INTR1090
        A PAIR OF GIVEN POINTS IS DETERMINED BY THE COORDINATES OF    INTR1100
        AND THE SLOPES AT THE POINTS.  COMPARISON INDICATES THAT THE  INTR1110
        CURVE OBTAINED BY THIS METHOD IS CLOSER TO A MANUALLY DRAWN   INTR1120
        CURVE THAN THOSE DRAWN BY OTHER MATHEMATICAL METHODS...       INTR1130
                                                                      INTR1140
        A DETAILED EXPLANATION OF THE METHOD CAN BE FOUND IN THE      INTR1150
        OCTOBER 1970 ISSUE, JOURNAL OF THE ACM, PAGE 589, ENTITLED:   INTR1160
        "A NEW METHOD OF INTERPOLATION AND SMOOTH CURVE FITTING       INTR1170
         BASED ON LOCAL PROCEDURES", BY HIROSHI AKIMA.                INTR1180
                                                                      INTR1190
                                                                      INTR1200
        A DESCRIPTION OF THE ALGORITHM USED PLUS THE ORIGINAL         INTR1210
        FORTRAN PROGRAM IS GIVEN IN THE OCTOBER 1972 ISSUE,           INTR1220
        COMMUNICATIONS OF THE ACM, PAGE 914, ENTITLED:                INTR1230
        "INTERPOLATION AND SMOOTH CURVE FITTING BASED ON LOCAL        INTR1240
         PROCEDURES", BY HIROSHI AKIMA.                               INTR1250
                                                                      INTR1260
                                                                      INTR1270
..................................................................... INTR1280
                                                                      INTR1290
                                                                      INTR1300
    SUBROUTINE  INTRPL(L,X,Y,N,U,V)                                   INTR1310
INTERPOLATION OF A SINGLE-VALUED FUNCTION                             INTR1320
THIS SUBROUTINE INTERPOLATES, FROM VALUES OF THE FUNCTION             INTR1330
GIVEN AS ORDINATES OF INPUT DATA POINTS IN AN X-Y PLANE               INTR1340
AND FOR A GIVEN SET OF X VALUES (ABSCISSAS), THE VALUES OF            INTR1350
A SINGLE-VALUED FUNCTION Y = Y(X).                                    INTR1360
THE INPUT PARAMETERS ARE                                              INTR1370
    L  = NUMBER OF INPUT DATA POINTS                                  INTR1380
         (MUST BE 2 OR GREATER)                                       INTR1390
    X  = ARRAY OF DIMENSION L STORING THE X VALUES                    INTR1400
         (ABSCISSAS) OF INPUT DATA POINTS                             INTR1410
         (IN ASCENDING ORDER)                                         INTR1420
    Y  = ARRAY OF DIMENSION L STORING THE Y VALUES                    INTR1430
         (ORDINATES) OF INPUT DATA POINTS                             INTR1440
    N  = NUMBER OF POINTS AT WHICH INTERPOLATION OF THE               INTR1450
         Y VALUE (ORDINATE) IS DESIRED                                INTR1460
         (MUST BE 1 OR GREATER)                                       INTR1470
    U  = ARRAY OF DIMENSION N STORING THE X VALUES                    INTR1480
```

```
         (ABSCISSAS) OF DESIRED POINTS                              INTR1490
THE OUTPUT PARAMETER IS                                             INTR1500
    V  = ARRAY OF DIMENSION N WHERE THE INTERPOLATED Y              INTR1510
         VALUES (ORDINATES) ARE TO BE DISPLAYED                     INTR1520
DECLARATION STATEMENTS                                              INTR1530
    DIMENSION    X(L),Y(L),U(N),V(N)                                INTR1540
    EQUIVALENCE  (P0,X3),(Q0,Y3),(Q1,T3)                            INTR1550
    REAL         M1,M2,M3,M4,M5                                     INTR1560
    EQUIVALENCE  (UK,DX),(IMN,X2,A1,M1),(IMX,X5,A5,M5),             INTR1570
   1             (J,SW,SA),(Y2,W2,W4,Q2),(Y5,W3,Q3)                 INTR1580
PRELIMINARY PROCESSING                                              INTR1590
 10 LO=L                                                            INTR1600
    LM1=LO-1                                                        INTR1610
    LM2=LM1-1                                                       INTR1620
    LP1=LO+1                                                        INTR1630
    NO=N                                                            INTR1640
    IF(LM2.LT.0)          GO TO 90                                  INTR1650
    IF(NO.LE.0)           GO TO 91                                  INTR1660
    DO 11  I=2,LO                                                   INTR1670
      IF(X(I-1)-X(I))     11,95,96                                  INTR1680
 11   CONTINUE                                                      INTR1690
    IPV=0                                                           INTR1700
MAIN DC-LOOP                                                        INTR1710
    DC 80  K=1,NO                                                   INTR1720
      UK=U(K)                                                       INTR1730
ROUTINE TO LOCATE THE DESIRED POINT                                 INTR1740
 20   IF(LM2.EQ.0)        GO TO 27                                  INTR1750
      IF(UK.GE.X(LO))     GO TO 26                                  INTR1760
      IF(UK.LT.X(1))      GO TO 25                                  INTR1770
      IMN=2                                                         INTR1780
      IMX=LO                                                        INTR1790
 21   I=(IMN+IMX)/2                                                 INTR1800
      IF(UK.GE.X(I))      GO TO 23                                  INTR1810
 22   IMX=I                                                         INTR1820
      GO TO 24                                                      INTR1830
 23   IMN=I+1                                                       INTR1840
 24   IF(IMX.GT.IMN)      GO TO 21                                  INTR1850
      I=IMX                                                         INTR1860
      GO TO 30                                                      INTR1870
 25   I=1                                                           INTR1880
      GO TO 30                                                      INTR1890
 26   I=LP1                                                         INTR1900
      GO TO 30                                                      INTR1910
 27   I=2                                                           INTR1920
CHECK IF I = IPV                                                    INTR1930
 30   IF(I.EQ.IPV)        GO TO 70                                  INTR1940
      IPV=I                                                         INTR1950
ROUTINES TO PICK UP NECESSARY X AND Y VALUES AND                    INTR1960
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       TO ESTIMATE THEM IF NECESSARY                            INTR1970
 40  J=I                                                        INTR1980
     IF(J.EQ.1)          J=2                                    INTR1990
     IF(J.EQ.LP1)        J=LO                                   INTR2000
     X3=X(J-1)                                                  INTR2010
     Y3=Y(J-1)                                                  INTR2020
     X4=X(J)                                                    INTR2030
     Y4=Y(J)                                                    INTR2040
     A3=X4-X3                                                   INTR2050
     M3=(Y4-Y3)/A3                                              INTR2060
     IF(LM2.EQ.0)        GO TO 43                               INTR2070
     IF(J.EQ.2)          GO TO 41                               INTR2080
     X2=X(J-2)                                                  INTR2090
     Y2=Y(J-2)                                                  INTR2100
     A2=X3-X2                                                   INTR2110
     M2=(Y3-Y2)/A2                                              INTR2120
     IF(J.EQ.LO)         GO TO 42                               INTR2130
 41  X5=X(J+1)                                                  INTR2140
     Y5=Y(J+1)                                                  INTR2150
     A4=X5-X4                                                   INTR2160
     M4=(Y5-Y4)/A4                                              INTR2170
     IF(J.EQ.2)          M2=M3+M3-M4                            INTR2180
     GO TO 45                                                   INTR2190
 42  M4=M3+M3-M2                                                INTR2200
     GO TO 45                                                   INTR2210
 43  M2=M3                                                      INTR2220
     M4=M3                                                      INTR2230
 45  IF(J.LE.3)          GO TO 46                               INTR2240
     A1=X2-X(J-3)                                               INTR2250
     M1=(Y2-Y(J-3))/A1                                          INTR2260
     GO TO 47                                                   INTR2270
 46  M1=M2+M2-M3                                                INTR2280
 47  IF(J.GE.LM1)        GO TO 48                               INTR2290
     A5=X(J+2)-X5                                               INTR2300
     M5=(Y(J+2)-Y5)/A5                                          INTR2310
     GO TO 50                                                   INTR2320
 48  M5=M4+M4-M3                                                INTR2330
NUMERICAL DIFFERENTIATION                                       INTR2340
 50  IF(I.EQ.LP1)        GO TO 52                               INTR2350
     W2=ABS(M4-M3)                                              INTR2360
     W3=ABS(M2-M1)                                              INTR2370
     SW=W2+W3                                                   INTR2380
     IF(SW.NE.0.0)       GO TO 51                               INTR2390
     W2=0.5                                                     INTR2400
     W3=0.5                                                     INTR2410
     SW=1.0                                                     INTR2420
 51  T3=(W2*M2+W3*M3)/SW                                        INTR2430
     IF(I.EQ.1)          GO TO 54                               INTR2440
```

```
 52    W3=ABS(M5-M4)                                                    INTR2450
       W4=ABS(M3-M2)                                                    INTR2460
       SW=W3+W4                                                         INTR2470
       IF(SW.NE.0.0)       GO TO 53                                     INTR2480
       W3=0.5                                                           INTR2490
       W4=0.5                                                           INTR2500
       SW=1.0                                                           INTR2510
 53    T4=(W3*M3+W4*M4)/SW                                              INTR2520
       IF(I.NE.LP1)        GO TO 60                                     INTR2530
       T3=T4                                                            INTR2540
       SA=A2+A3                                                         INTR2550
       T4=0.5*(M4+M5-A2*(A2-A3)*(M2-M3)/(SA*SA))                        INTR2560
       X3=X4                                                            INTR2570
       Y3=Y4                                                            INTR2580
       A3=A2                                                            INTR2590
       M3=M4                                                            INTR2600
       GO TO 60                                                         INTR2610
 54    T4=T3                                                            INTR2620
       SA=A3+A4                                                         INTR2630
       T3=0.5*(M1+M2-A4*(A3-A4)*(M3-M4)/(SA*SA))                        INTR2640
       X3=X3-A4                                                         INTR2650
       Y3=Y3-M2*A4                                                      INTR2660
       A3=A4                                                            INTR2670
       M3=M2                                                            INTR2680
DETERMINATION OF THE COEFFICIENTS                                       INTR2690
 60    Q2=(2.0*(M3-T3)+M3-T4)/A3                                        INTR2700
       Q3=(-M3-M3+T3+T4)/(A3*A3)                                        INTR2710
COMPUTATION OF THE POLYNOMIAL                                           INTR2720
 70    DX=UK-P0                                                         INTR2730
 80    V(K)=Q0+DX*(Q1+DX*(Q2+DX*Q3))                                    INTR2740
     RETURN                                                             INTR2750
ERROR EXIT                                                              INTR2760
 90  WRITE (6,2090)                                                     INTR2770
     GO TO 99                                                           INTR2780
 91  WRITE (6,2091)                                                     INTR2790
     GO TO 99                                                           INTR2800
 95  WRITE (6,2095)                                                     INTR2810
     GO TO 97                                                           INTR2820
 96  WRITE (6,2096)                                                     INTR2830
 97  WRITE (6,2097)    I,X(I)                                           INTR2840
 99  WRITE (6,2099)    L0,N0                                            INTR2850
     RETURN                                                             INTR2860
FORMAT STATEMENTS                                                       INTR2870
2090 FORMAT(1X/22H   ***    L = 1 OR LESS./)                            INTR2880
2091 FORMAT(1X/22H   ***    N = 0 OR LESS./)                            INTR2890
2095 FORMAT(1X/27H   ***    IDENTICAL X VALUES./)                       INTR2900
2096 FORMAT(1X/33H   ***    X VALUES OUT OF SEQUENCE./)                 INTR2910
2097 FORMAT(6H    I =,I7,10X,6HX(I) =,E12.3)                            INTR2920
```

```
2099 FORMAT(6H   L =,I7,10X,3HN =,I7/                                   INTR2930
     1      36H ERROR DETECTED IN ROUTINE     INTRPL)                   INTR2940
      END                                                               INTR2950

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                           END OF THESIS
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ABSTRACT

Fiber light guides are used in conjunction with holographic interferometry. A Michelson interferometer was constructed to test for temporal coherence of light passing through fiber optics. A finite-fringe hologram of a no-flow condition was taken to prove the feasibility of applying fiber optics to this field of flow investigation.

The effect of opaque bodies on interferometric data inversion was sought. Two schemes for replacing the missing fringe data were used to see if the accuracy of the calculated density fields could be enhanced.

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